#### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

 In re Patent Application of
 Date: Dec. 18, 2009

 Applicants: Bednorz et al.
 Docket: YO987074BZ

 Serial No.: 08/479,810
 Group Art Unit: 1751

 Filed: June 7, 1995
 Examiner: M. Kopec

Appeal No. 2009-003320

For: NEW SUPERCONDUCTIVE COMPOUNDS HAVING HIGH TRANSITION TEMPERATURE, METHODS FOR THEIR USE AND PREPARATION

Mail Stop: Appeal Brief – Patents Commissioner for Patents United States Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450

## SUPPLEMENT 2 REQUEST FOR REHEQRING UNDER 37 C.F.R. § 41.52 (a)(1) Of

Decision on Appeal dated 09/17/2009

#### ATTACHMENTS

Please charge any fee necessary to enter this paper and any previous paper to deposit account 09-0468.

Respectfully submitted,

/Daniel P Morris/ Dr. Daniel P. Morris, Esq. Lead Attorney Reg. No. 32,053 (914) 945-3217

IBM CORPORATION Intellectual Property Law Dept. P.O. Box 218 Yorktown Heights. New York 10598

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#### [54] OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

- [75] Inventors: Gordon Henry Cook, Cadby, England; Peter Arnold Merigold, Prestatyn, Wales
- [73] Assignee: The Rank Organization Limited, London, England
- [22] Filed: June 11, 1971
- [22] Filed: June 11, 1971
  [21] Appl. No.: 152,254

Related U.S. Application Data
[63] Continuation-in-part of Ser. No. 309,208, Sept. 16,
1963 abendoned

#### [56] References Ched

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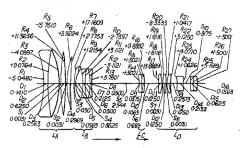
Primary Examiner-John K. Corbin
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#### (7) ABSTRACT

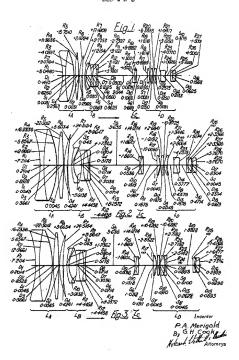
A zoom lens having an improved zooming range and

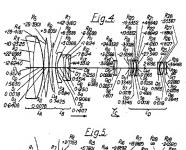
comprising a convergent first member which for a given object distance remains stationary during the accoming relative movements, an axially movable divergent second member behind the first member having equivalent focal length fo lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the same of variation, an axially movable divergent third member behind the second member having equivalent focal length fo lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5% and 2.5% and the total axial movement of the third member in the range lies numerically between 0.25fc and 0.5fc, the minimum axial separation between the second and third members occurring when the equivalent focal length of the object is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between 0.5% and 1.0%.

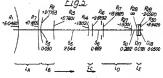
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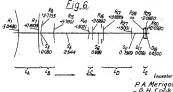


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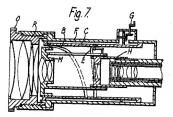


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#### OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

This application is a continuation-in-part of our prior application Ser. No. 309,268, filed Sept. 16, 1963, now

This invention relates to an optical objective of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, 10 the equivalent focal length of the objective to the fwhilst maintaining constant position of the image plane, whereby the scale of the image can be varied the objective being corrected for spherical and chromatic aberration, come, astigmatism, field curvature and distortion. In this type of objective, accommoda- 15 tion for change of object position is usually achieved by imparting a movement, independent of the sooming relative movements, to the front member of the objec-

Many difficulties arise in the design of such objec- 20 tives, and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this have usually involved the use of relatively complicated mov- 25 able members in the objective in order to make it posstble to stabilize the aberrations throughout the range of variation, such stabilized aberrations then being compensated in a stationary sear member of the objective which also serves to locate the resultant image plane in a convenient position. This is turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems is controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear ralationship to the movement of the 200m control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions of have introduced too severe optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the zooming movements for verying the equivalent focal length, so that this member is concerned only with focussing movements and is relieved of the complication of superimposing focussing movements on zooming movements, Such an arrangement is utilized in the present invention, wherein the primary object is to provide an improved arrangement of the movable zooming system of the objective, which can be employed with various different arrangements of the front member and will cooperate therewith to enable aburration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

#### BRIEF SUMMARY OF THE INVENTION

The optical objective of the zoom type according to 65 of the members without risk of fouling between the the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the gooming relative

movements, the second and third are divergent and movable, and the fourth is convergent and stationery, the minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths  $f_n$  and  $f_C$  respectively of the movable second and third members lie numerically respectively between 4 and 8 times the minimum value of the ratio of number of the objective in the range of variation and between 5 and 10 times such minimum ratio, the divargent mayable second member consisting of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent compound comp nent and performing during the range of variation a total axial movement lying numerically between 1.5/s and 2.5 fe, whilst the divergent movable third member consists of a doublet component having a front surface concave to the front with radius of curvature lying numerically between  $0.5f_c$  and  $1.0f_c$  and performs during the range of variation a total axial movement lying sumerically between 0.25fc and 0.5fc.

Several specific examples of optical objectives as above described will be given later on in this specification, and a table will be found after the first example, together with an accompanying explanation showing the effect of varying those parameters for which ranges of variation are given in the preceding paragraph within the ranges specified in that paragraph It is to be understood that the terms "front" and

'rear", as used herein, relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention in addition, the term "total axial movement" is used to refer to the total distance moved by a member during sooming from one end of the range to the other, independently of the direction of movement. Thus, a ember may move forward and then back during the range of variation, and in this case the total axial movement is the numerical sum of the forward distance moved plus the rearward distance moved.

is should also be made elear that the term "internal contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the arithmetic mean between the radii of curvature of the individual contacting surfaces, whilst the optical power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall dimensions of the objective as small as pos sible and achieving the best compromise between the diameters and the relative spertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movementa members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures

of the individual members, and at the same time to assist towards the desired stabilization of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

#### FURTHER FEATURES OF THE INVENTION The compound component in the divergent movable

second member preferably includes at least one conmade of materials whose Abbe V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic cherration

For assisting towards stabilization of astigmatism and 15 distortion, the radius of curvature of the front surface of the simple meniscus component of the second member proferably lies numerically between 1.5fe and 3fm and further assistance towards stabilization of astigmaism can be obtained by arranging for the radius of curvature of the year surface of such component to lie numerically between 0.66fs and 1.0B. B.

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature lying numerically between 1.5fa and 3fs, the rear surface of such component being convex to the front with radius of curvature lying numerically between 3fs and 6fs, thus assisting towards stabilization of spherical aberration and coma.

Whilst such compound component may consist of a doublet component, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials 35 for the various elements, facilitates correction of chromatic abercation and the desired stabilization of the other observations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can 40 also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one an- 45 other by more than 0.15. The arithmetic mean between the Abbe V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chro- 50 matic aberration.

The doublet con ponent constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature lying numerically between  $0.5f_0$  and  $f_0$ , the differonce between the mean refractive indices of the materials of the two elements of such component lying between 6.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25. These features contribute towards the desired stabilization of the spherical aberration and come and also facilitate individual correction of the third member for chro-. matic sherration

As in the case of the second member, it is preferable to employ materiels for the elements of the third member having mean refractive indices greater than 1,65, in order to avaid excessive surface curvatures and thus

facilitate the attainment of a wide relative aperture for the membe

A movable system arranged in the manner above described in accordance with the present invention is suit-5 - able for use with various different arrangements of the first member of the objective, but it is especially advan tageous for such member to have one or more of the

following characteristics: A. The first member is preferably convergent and vergent element and at least one divergent element 10 may comprise a front meniscus doublet component with its front and rear surfaces concave to the front followed by two simple convergent components, the front surface of the doublet component having dispersive op tical power lying numerically between 0.5/f, and 1.0/f,

where fa is the equivalent focal length of the first member. These features permit the rear nodel point of the first member to be far to the rear and preferably behind the rear surface of the member, for cooperation with the forwardly located front nodal point of the second

member 8. The internal contact of the meniacus doublet component of the first member may be dispersive and convex to the front with radius of curvature between 1.5% and 3f., the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15. These features contribute towards stabilization of spherical aborration and astigmatism over the desired focussing range to suit different object distances

C. The two simple components of the first member may together have a combined equivalent focal length between 0.75fa and 1.25fa, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than 4f, and greater than twice the radius of curvature of the froot surface of the second of such simple components, which latter radius of curvature may in turn be greater than 0.75fs. These features assist towards stabilizing the aberrations, especially spherical abstration and astigmatism, not only throughout the range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D. The rear surface of the rear component of the first member may be convex to the front with radius of curvature between 2f, and 7fa. This feature contributes towards stabilization of primary astigmasism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E. The axial thickness of the meniscus doublet component of the first member may be less than 0.25/, and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than 0.075fa. These features contribute to wards the desired rearward location of the rear nodal

point of the first member. F. The arithmetic mean between the Abbe V numbers of the material of the three convergent elements of the first member may exceed by at least 20 the Abhe

V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G. The equivalent focal length f, of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective. This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first mem-

ber as small as possible.

H. if desired, an achromatic doublet component may be provided, which can be placed at will behind the 3 lations as is well understood in the art. rear member of the objective to increase the value of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the ob- 10 jective to be stationary and to be located hebind the movable third member of the objective.

#### DESCRIPTION OF EMBODIMENTS

Some convenient practical examples of zoom objec- 15 tive according to the invention are illustrated diagrammutically in the accompanying drawings, in which FIGS. 1 - 4 respectively illustrate four examples

(FIG. 4 being on half the scale of FIGS, 1 - 3) FIGS. 5 - 6 show the example of FIG. 1 (in skeleton 20 form) modified by the addition respectively of two alternative constructions of achromatic doublet component detachably mounted behind the rear member of the objective, and

FIG. 7 is an axial section through a tens mount having 25 suitable zoom control element for use in carrying out the invention

Numerical data for these six examples are given in the following tables (numbered correspondingly to the figures of the drawings), in which R, Rg... designate 30 the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, D1, D2 . . . designate the axial thicknesses of the individual elements of 35 H the objective, and S1, S3 . . . designate the axial air separations between the components of the objective. The tubles also give the mean refractive indices ng for the d-line of the spectrum and the Abbe V numbers of the materials from which the various elements of the objective are made, and in addition the clear diameters of the various surfaces of the objective

The second section of each table gives the values of the three variable axial air separations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value  $F_a$  to its maximum value  $F_m$  are also given, together with the corresponding values of log F.

Some of the tables also have a third section giving the equation defining an axial section through an amberic surface provided in the stationary rear member of the objective, the radius of curvature given for such surface 55 in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms of P. The insertion of equals (100) signs in the radius colmns of the tables, in company with plus (+) and minus 60 (-) signs which indicate whether the surface is convex or concave to the front, is for conformity with the usual Patent Office custom, and it is to be understood that these signs are not to be interpreted wholly in their mathematical significance. This sign convention agrees 65 with the mathematical sign convention required for the computation of some of the aberrations including the primary aberrations, but different mathematical sign

6 conventions are required for other purposes including computation of some of the secondary obstrations, so that a radius indicated for example as positive in the tables may have to be treated as negative for some calcu-

	EXAD	rens 1		
Kadięs	Tinckness or air sepanation	itedraetšvo Index ste	Abbs V liquidite	Clear distantes
R1 ∞~5.0180	D: -0.1410	>. 7647	28.10	St. 3.4425
R <sub>1</sub> = +9.5564 R <sub>2</sub> = -4.6967	81++0.6081	1.50009	50.35	Ste 8.4710 Ste 2.4870
R: -+11.3630 R:15.7630	D1=0.2563	1,717	47,90	Re 8.2786 Re 8.2680
R4 = 1-8.9225	S <sub>2</sub> ==0.0031 D <sub>2</sub> =0.0063	1,717	47.00	R <sub>4</sub> 8.3685
Rs =+\$7.3800 Rs =+\$2.738	E <sub>1</sub> =Variable			R: 8.0007 R: 1.7000
Rs ++1,2134	De=0.0865 Be=0.8825	1.40784	86.19	R, 1.6812
Rp+-2.7357 Rc++3.1121	Da=0.6890 Da=0.2125	1,69734	35.19	Bu 1.4783 Bu 1.4093
Higa - 3.1131 No 45.7681	De+9.0908	1.80786	95, 10 85, 10	Ru 1.8947
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Res = +1,0417	Se-0.0001 Don-0.1000	1,800	88.67	SC+ 0.5502 Rot 0.8858
tor≈+3.5290 tor≈4.0770	He=0.2213 -	1.83	00, 81	R <sub>27</sub> 6.8602 R <sub>10</sub> 6.7580
3 <sub>04</sub> ← (-5,0000	D1=0.3323 flor=0.3325	1. 7293	38.88	No. 9.8507
kn=+4.1650 kn=+16.5001	30,000 mag (1	1, 7288	26.32	Res 0.7107 Res 0.7200
ice≠~1.5001	Dawn.1585	1. 61453	\$0.21	Ber 0.7225

03033 1.11409

Equation for aspheric surface R

· Ampheric.

# = - 4.077 + √16.62183-19 - 0.02459203 y\*+ 0.08899172 y\*

~ 0.2440590 y\* ~ 0.07442450 y#

The foregoing Example describes a complete thick lens design, with values calculated in many cases to the fourth decimal place, and several additional Examples of this type will be given subsequently

It is, however, obviously impractical to provide such fully calculated thick lens designs for values broadly distributed throughout the previously specified ranges for all the significant parameters.

However, in order to show the effect of altering the principal parameters within the ranges specified for those parameters, and demonstrate the practicality of designing lenses having parameter values near the extremes of the specified ranges, an illustrative table is given below. The parameters given are all thin leasy parameters from thin leasy construction on which Example 1 is based) and the effects of these parameter variations are shown on the dimensions of the 5 overall objective and the relative apertures (f-numbers) of the first three members.

#### In the following table:

- Fe is the focal length of the second member;
- Fe is the focal length of the third member;
- $T_R$  is the total axial movement of the second member;  $T_C$  is the total axial movement of the third member; R is the minimum value of the ratio of the focal
- K is the minimum value of the ratio of the focal length of the complete objective to its f-number; L is the overall length from the front of the objective to the focal plane;
- D is the maximum diameter at the front of the objective;
- F<sub>wt</sub> is the relative aperture of the first member; F<sub>wt</sub> is the relative aperture of the second member;
- F<sub>ret</sub> is the relative aperture of the second member; and and F<sub>ret</sub> is the relative aperture of the third member.

The four critical this been parameters as forch in the fifth paragraph of this specification and in the using schim are  $F_a$ ,  $F_a$ ,  $F_a$ , and  $F_a$ , and their values for Example 1 are shown in fine 1 of the table. In line 2,  $F_a$  is pure equal to the lower limit (AR) of the main claim, and in time 3 equal to the open limit (AR) for the main claim, and in lime 3 equal to the open limit (AR). In line 4 and 5  $F_a$  manner in lines 6 and 7 and lines 8 and 9. It is not possible to vary the foot parameters completely independently of one another (this is referred to again later), and in fact when one parameter is set to an end limit, at least two 4 the other lines been adjusted, in the ta-5 of the other lines been adjusted, in the ta-5 of the other lines been adjusted, in the ta-5 of the other lines been adjusted, in the ta-5 of the other lines been adjusted, in the ta-5 of the other lines been adjusted, in the ta-5 of the other lines of the other lines been adjusted, in the ta-5 of the other lines of the other lines are of the other lines of the other lines and the other lines of the other lines are of the other lines are other line

Line 3 shows the effect of putting F, to its upper
limit. Conversely, from the changes in L, D, F., FA
and Free it can be seen that such a modified thin lens
construction would be suitable for development of a
final objective of relatively simple construction con-
structed to cover relatively large image format dimen-
sions (at which scale high complexity would not be per-
missible) at a smaller relative aperture than Example I.
Lines 4 and 5 show identical effects achievable by

Lines 4 and 5 show identical effects achievable by putting Fc at its lower and upper limits.

Line 6 shows the effect of putting the total axial

movement of the second member at its upper limit. In fact, in order to do this, it is necessary to put at least either Fe or Fe at or near its end limit. This is dictated 35 by the fundamental laws of optics, also bearing in mind the requirement to keep the focal range roughly the same. However, the effect is now not quite the same as in lines 2 to 5, because one axial movement now also 26 lies at its end limit. Thus, the change in L and D from Example I is reduced, while the relative aparture of one member (the third member) is increased but the other two are reduced. Lines 7 to 9 show similar effects; in extent from Example I, as also are Fat, Fat and Fat. Reverting to line 5 in particular, this modification is suited to a moderately small but not extremely small dimensional scale of final objective having a medium relative aperture, wherein the smaller relative aperture of the third member either permits its complexity to be rean duced or, more usefully, its existing complexity utilized to achieve an extremely high standard of observation correction. Corresponding but slightly different effects can be seen from the modifications of lines 7 to 9.

In general therefore, it can readily he seen from the table how the parameters of the mein claim can be taken to their and limits to provide differing effects suited to differing initial requirements. The lens de-

	Fo	Fc	Tg	Te	Į.	ç	Fai	7.0	7.0
Example 1	-3.67	~1. 63	7.30	0.46	3,63	2,91	1.50	1.0	7, 29
Fn-13 (48)	-1.0	-1.82	2.74	0.50	3.98	2.50	1, 34	0.42	2.10
×-20 (953)	-2.2	-L 82	3,95	0.79	4,30	3.13	1.74	1.69	7, 39
Sc ~1.25 (5 R)	-1.47	-1.25	2 +6	8.50	2.13	2,40	1,40	1.00	1, 67
2-2.5 (LGR)	-1.65	-2.00	2.33	2.72	1.07	2.04	1.75	0.08	5, 07
\$2.5 (2.5) phase me	m5.0	~3.20	2 80	0.60	3 18	4.02	1.44	0.81	2, 38
Code BAPal	-20	~1.25	3.00	0.83	3.65	先数	1.34	5, 68	1, 36
(cfi.66 (0.29 Fc)	-1.8	-2.80	2.53	0.46	8.24	2.60	1.45	0.10	V. 24
Te6.79 (0.0Fe)	-20	L. 44	3 23	5.72	\$ 102	2.00	1, 63	1.85	1, 47

Example I is a zoom lens intended for construction to a medium dimensional scale to cover average format dimensions.

In line 2, the effect of putting F<sub>2</sub> to its lower limit is to reduce L and OF<sub>2</sub>, W<sub>1</sub>, and F<sub>2</sub>, are the orequoted, menning that each individual member has a wider relative aperture. Because of hier wider fertilize apertures, these members would have to be more complex (con-5) in Example, it, moder to achieve the anne high standard of aberration correction. However, this greater complexity would be acceptable for a zoom objective built to a small differentiated as a zoom objective would be acceptable for a zoom objective built in the acceptable for a zoom objective would readily be possible in view of the reductions in Land D Therefore, a zoon tens within the acope of the main takin, with F<sub>2</sub> at or near is lower limit, would be preferred for a lens of wider relative aperture but con-65 structed to a smaller dimensional seat than Example

signer given the main claim and having a particular end requirement can work accordingly.

The table also demonstrates the sense of the end limits. For example, to take Fy below the value of 1.8(4R) in line 2 would be further to decrease L and D and further widen the relative apertures of the second, third and fourth members. Obviously a question of opinion is involved at this point, but the opinion of the inventor is thist the complexity of construction for the second to fourth members, in order to achieve good aberration correction at the further widened relative aperture. would render a practical construction a noncommercial proposition. Likewise to take F. beyond the value of 2.0(8R) in line-3 would only permit construction of a practical corrected objective to such a large dimensional scale that it would find no useful anplication. The same factors siso arise in the modifications of lines 6 to 9, when coupled with the requirement

to maintain a large range of variation of focal length, which is an essential object of the invention.

9				-,.	10					
	RXAN	H WATER				Bp		1	1	Ba 1.593
Radita	Thickness or	Redructive index n	Abbs V	Class diameter	•	Bn=+8,3572	Dywd.0714 Sywyariable	1.69784	50, 10	Ru 1.9161
Res - 7.2134	_	1	1	B. 4.9592	~	Ha 1,8503	D0.0000	1.00754	58, 19	Hts 1.1188
Ram-112.0002	D:=0.3044	1, 7647	20.10	33, 6,0542	5	Box+1.8803	E3: c==0.3818	1,7847	28, 16	Rec 1.1791
Ra==-5.8567	Dr=0.8028	1.81507	82.35	36e 8.0854		, 35°+54'1854	Sempartable			Ru 1.385
Rew+16.2888	81=0.0368	l		R. 4.8065		Represe	Do +0 1311	1.894	36.87	Rej 5,2820
ft+=~28,5002	Ds=0.8881	1.7170	47.90	R. 4.8014		Rese -2.3833	Hr=8:0045			Rts 1,3084
Ft+w-j-5.000a	8,440.0046		67.80	Fig 4.6885	10	R <sub>19</sub> = -140,0393 R <sub>19</sub> =-40,0393	Do =0.1810	t, 594	38.87	Re 1,533s
Rro+98.5334	Dy=0.6381 Sy=Variable	1,7170	\$7,90	Rs 4.8807		Ro-+2781#	Fe=0,6045			Ro 1.500
H4-4-8.9947	D <sub>1</sub> =8.0884	1.66784	F8.19	Ry 2.4288		Ro2.5813	Du=0.9018	L 65342	53. 12	Rp 1 300
Re-+1.7302	8,+0,5179	A-00744	1	R, 2.1161		Rus-23142	E++0.0100	[		Rn 1.300
Ru=-39183	Devil.0114	1.09734	55, 19	Ru 2.1018	15	Rawoo	1750-01.0000	1,17880	19.38	Bo 1.33M
Ru=+1.4458	55+wb.8088	1.7867	25.10	B11 2.0132		Romo	Bu ≈ 1.8058			Res 0.0000
Ro	Da+0.0744	5.00754	86.10	Bn 1.6325		Raw+1,4200	Dos=0.0803	£ 72850	55.65	Res 0.0000
Rep. + 9.2572	Spec Vertibile	-,		Bu 1.0161		Rg =+5.8427	R <sub>15</sub> ≈ 0.0293			Bp 0.5800
Rsper - 1 #855	D+=0.0098	1, 60754	50, 10	\$647.1880	20	Ran- 27507	Da=9.3939	1,59786	88, 19	Bts 0.0000
R <sub>36</sub> ≪+1.9866	De=0.1518	5. 1961	20, 16	\$100 2.2792						8
Ros+H.IMI	Sew Vectobile	- 12		Sits 1.1857		5 5	S462 1,0310	P	log P	*****
By=~10.0006	Do-0.1905	1,8306	64.20	Rep 1 2553		1.59156 2.0	31054 1,3076	1.77927 1	3.25	
Ba1.9192	80.0NS			Rep 1.2961	25	2.76329 0.8 3.64395 0.2	1,08422 13005 0,83569	3.16227 5.62339	3.50	
Res=+3.6841	Dow0.1808	1,6159	64.20	R <sub>9</sub> 1.8110			3796 0.23984	10,00000	1.00	
Ber==10.8705 f	84=0.0045			Eq. (.8023			BXAMY	VI 83		
Bu 1.8446	Dp=0.1875	1.5100	64.90	Ra Luny			Thickness or	Rabactive	4112m 1	Pleas
Hara-4.3815	He=0.4875*		•	R <sub>80</sub> 3,2226	30	Radius	Thtokness or our separation	lader ng	Apps V somber	Clear disageter
R:++19176	3>1=0.8797	1,7988	25,66	Ro 1,000 Ro 0,000		#Ip=-12.6965				R1 8.6135
Rowoo	Ba=0.8716	1		Rg 1,000		H <sub>4</sub> =+22.6983	\$1. ≈9.8628	£.7847	25, 10	St. 8,0400
R <sub>0</sub> = +2 3255	1>u+0.0009	1.7285	15.60	Ro 1.0068		State - 10, 2505	Dr=1.0600	1. 51300	59,34	84, 8,7308
Rgo-2386	Du#4.2004	1,61832	59, 27	Re 1.0185	35	R4++35.4581	S. wd. 3018			FL 84514
Rpw+6,3877	S-J++0.0015			Res 1,0084		R4+-26.5500	De+0.5459	1.7173	47, 90	Rt 8.4002
Report - 6, 7870	D <sub>17</sub> e=0.2804	1 51362	88.27	R <sub>24</sub> 0.0776		Eg++++0.8081	St =0.0078			Re 7.7612
*Authoria.				104 113110		R:+++42.0590	Dc=0.9425	1.7176	47,95	St; 7.6793
A. gonton		***			40	84	Se-Variable	1.6980	86.89	Ry 4.2516
S4 S4 0.04318 3.63	462 0.98730	F 1.00000	0.00			24-42-0358	Dy=0.1497 Ey=0.9983	T. edests	26.30	R, 3 7648
1.59156 2,01	054 1,06300	1.77827	0.25			Ray - 6,3897	Da+0.1000	1. 00881	No. 33	R <sub>30</sub> 8,889 S
	001 0.79109		0.50			Rp - +7.8124	D;+6.8814	1,795/2	29.06	Ra 3,5240
4.23190 0.23	796 0.19524	10,00000	1.00		45	R <sub>N</sub> =~7.8124	Dy=0.1280	1. 4.631	26.85	H <sub>N</sub> 8,4820
Equation for	ascherie wef	nce R.				Rq=+14,3012	HewVariable	A. 4.mea	20.00	Rs 8.3324
						Rus ~8,2808	D <sub>6</sub> =0.0034	1.6681	26.83	R <sub>10</sub> 1.0329
₹ = ~ 4.2315			0.0166	5805 y* ÷		Rp=14.288	Dow0.9687	3, 19502	25.00	Rp 2.6530
		0843 Z*			50	京都,松十年4月	Pyer Variable			R1 2.0774
0.0	10176346 y*	~ 0.00553	820 X10			N.194-12.5008	1312-0.2869	3. 65631	85.60	B20 2.3874
	EXAM	eLX III				Rom-2.702#	Sp#0.0015			Ha 7,380
	Tolokness or alr separation	Refractive index ng	Abbe y	Close		Rum-1-59.5852	Dag et 6, \$563	3,45081	84.80	Ro 2.5222
Redigs	Pla sedeutations	South #1	phingper		22	R <sub>20</sub> = −10.5852 R <sub>21</sub> = → 1.8640	Zg+8,0076			Res 2,8891 Res 2,2837
R 17.0661	D1 will 2016	1.7967	28, 16	R; 4.9192		R <sub>11</sub> ≈ 1.8040 R <sub>11</sub> ≈ 1.8040	Dio#6.4889	3, 54817	84.97	Ras 2.200
Re0487	D₁ ≈ 9.8038	1.55307	56.25	Rg 4.9643 Rg 4.9858		Ra-4,1200	8 <sub>8</sub> ≈0.0088			R# 2226
R <sub>1</sub> =+16.33%	41 +0 9965			R: 4.8164		Bn=+27.8461	10 <sub>5</sub> , er G. 1588	1,7282	15.00	Ro 21508
Re==22.503	Ds == 0.3891	3, 7370	47.9b	R. 4.8014	60	Ba-so	B <sub>10</sub> ≈2.8336		-	Ro 1.7174
Re=+5.00M	R <sub>1</sub> ~ 8,004.5			R4 4.4820		Bu=+1.8127	Daywii.1883	3. 16134	25.16	Bo 1.7874
Str +0.0004 Str +94.3654	D-~0.4281	3-7570	47. 90	Ry 4.5007		Na -41.8027	Big=0.0029			Re 1.7892
Re=+3.0947	New yariahir			E4 2 4295		Bar-5,5397	1311-0.0569	1.66081	86.69	Rp 5,7741
Re-+1.7301	Dy=0.0004	1. 56794	M: 19	Be 2.5101	65	Bar-+5.660	S <sub>10</sub> ≈ 0.000a +	- 1		Bp 1.7584
Re~~2.6818	n8.8\$7€	1		Ru 2.1014		Ba-sa	D <sub>12</sub> ≈0.3880	L ENGS	35.00	Res 1.7100
Res +1.1158	134 0.0754	1.50784	Sã, 16	Bq 2,0183			E .	:		
	10 m 0.5088	5.7847	20, 10			* Authorit.				

Equation for aspheric surface Res

 $\underline{x} = +3.9463 - \sqrt{18.57328 - \underline{y}^2} + 0.00427020 \underline{y}^4 -0.00777096 \underline{y}^4 + 0.00721693 \underline{y}^{10}$ 

In all these examples, the maximum value Fe of the 10 equivalent feeal length F of the objective is ten times the minimum value F, thereof. Example I is corrected for a relative aperture f/4.0, whilst Examples II and III are each corrected for a relative aperture /2.8, and Example IV is corrected for a relative aperture of f/1 6. Examples II and III differ from one another solely in the stationary rear member La, the front three members L., L. and L. being identical in the two examples. Such members LA, La and Lc are in fact similar to the front 20 three members La, La and Lc of Example I, the dimensions being scaled up from those of Example I in the ratio of the f-numbers, that is in the ratio of 4.0/2.8. The roar members Lo in Examples II and III are, however, not scaled-up versions of the rear member Lb of 25 Example 1. The front three members La, La, Lc of Example IV, which includes yet another alternative construction of rear member Lo, are of the same general type as those of Examples I-III, but their numerical dimensions differ somewhat from a ver- 30 sion of those of Example I scaled up in the ratio 4.0/1.6.
All these examples cover a semi-angular field of view

All these champies cover a semi-angular tield or view waying from 27 objects at F<sub>1</sub>, vo 27 objects at F<sub>2</sub>, vo 3 objects at F<sub>3</sub>, vo 3 objects at F<sub>4</sub>, vo 4 objects at F<sub>4</sub>, vo 4 objects and the satisfancy rear number L<sub>4</sub>, vo and the satisfancy rear number L<sub>6</sub>. Vo 4 objects at F<sub>4</sub>, and has diameter 40 5.86 F<sub>2</sub>, in Example II the disphragm is 0.0325 F<sub>2</sub> in front of the surface R<sub>3</sub>, and has diameter 40 1.2240 F<sub>4</sub>, in Example III the disphragm is 0.1375 F<sub>4</sub>. The standard of the surface R<sub>3</sub> and is 1.240 F<sub>4</sub>, in Example III the disphragm is 0.1375 F<sub>4</sub> in front of the surface R<sub>3</sub>, and has diameter 40 1.240 F<sub>4</sub>; in Example IV the disphragm to 0.2407 F<sub>4</sub> in front of the surface R<sub>3</sub>, and has diameter 2.144 F<sub>4</sub>.

The back focal distance from the rear surface of the 45 objective to the image plane is 2 8301 F<sub>s</sub> in Example 1, 2.6761 F<sub>o</sub> in Example II, 2.3027 F<sub>s</sub> in Example III and 1.7878 F<sub>s</sub> in Example IV.

The equivalent focal length  $f_i$  of the stationary first member  $L_i$  is +4551  $F_i$  in Example I. 4-63464  $F_i$  in Example II. 4-63164  $F_i$  in Example III. 4-63164  $F_i$  in Example III. 4-63164  $F_i$  in Example III. 4-6316  $F_i$  in Example III.

gence.
In all four examples, the convergent stationary front 65
member L, consists of a memiscus doublet component
followed by two convergent simple components. The
front surface R, of the doublet component is concave
to the front and has dispersive optical power numeri-

cally equal to  $0.155/F_0$ , or  $0.692/f_0$ , in Example 1,  $0.010/F_0$ ,  $v_0.692/f_0$ , in Example 11 and III, and to  $0.063/F_0$ , or  $0.692/f_0$ , in Example IV. The internal consetts  $R_0$  of the doublet component is dispersive and convex to the front and has radius of curvature equal to 0.397,  $f_0$ , in all four examples. The difference between the mean refractive indices of the materials of the two demonstrat of such doublet component is 0.27 in all four

The combined equivalent feeal length of the two timple component of the fitte method. Is 4 0018 F<sub>1</sub>, in Example 1, 5.7162 F<sub>1</sub> in Example II and III, and 10.0064 F<sub>1</sub> in Example IV on 0.084 F<sub>1</sub> in Elfour examples. The radius of curvature R<sub>1</sub> of the front surface of the first of such simple components is 2.551 f<sub>1</sub> in all four examples, and the radius of curvature R<sub>2</sub> of the front surface of the second of such insight components in convex to the front which the second simple component is convex to the front with radius of curvature 3.837 j<sub>2</sub> in all four examples.

The axial thickness (D, + D<sub>i</sub>) of the meniscus decided component of the first member L<sub>i</sub> is 0.766 F, in Example 1, 1.094 F<sub>i</sub> in Example 11 and III, and 1.916 F<sub>j</sub> in Example 1, 1.094 F<sub>i</sub> in Example 13 and III, and 1.916 F<sub>j</sub> in Example 1V<sub>i</sub> or 0.127 f<sub>i</sub> in all four examples ments (D<sub>i</sub> + D<sub>i</sub>) of the first member is 0.538 F<sub>j</sub> in Example 1, 0.790 F<sub>i</sub> in Example 11 and III, and 1.383 F<sub>i</sub> in Example 10, 0.790 F<sub>i</sub> in Example 13 four examples 10 Example 10 Example

Of the arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member 1,4 in all flour examples is 50.72 and thus exceeds the Abbe V number of the material of the divergent from telement by 24.62.

The maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective is 2.5 F<sub>s</sub> in Example 1, 3.57 F<sub>s</sub> in Example 1 and III, and 6.25 F<sub>s</sub> its Example IV, so that in all four examples F<sub>s</sub> is 1.782 times such maximum value.

in all four examples, the minimum separation between the movels excend and third members  $L_p$  and  $L_c$  occurs when the equivalent focal length of the obscittive in 1-45  $F_p$ , and the numerical values of the 5 equivalent focal length  $f_p$  and  $f_p$  of such members are respectively 5.88 and 7.27 times the minimum value of the relation of the equivalent focal length of the objective to the Faunther of the objective or the Faunther of the objective

The moubble second member L<sub>2</sub> is all four complete Omnitist of a divergent simple memicione component with its surfaces convex to the front followed by a divergent richer to component taking a convergent clienter between two divergent elements, and its total said between two divergents and its total said for the range of variation in summiring years to 19.4 pt. The front and reas surfaces Component respectively have raid of conventue numerically equal to 1.66 f. in 16.5 in Example I.-Ill and 3.99 f. in Example I. Beample [W.

The movable third member  $L_c$  is all four examples consists of a doublet component, whose front surface  $R_{t,i}$  is concave to the front with radius of curvature numerically equal to  $0.72 f_c$ , and the total axial movement (the numerical sum of an initial forward movement

cally equal to 0.72 f. The difference between the mean refractive indices of the materials of such doublet composent is 0.087 in Examples I - III and 0.088 in Example IV, the difference between their Abbe V anubers being 30.09 in Examples I - III and 30.24 in Example IV.

In all four examples, the various aberrations are well to the property of the

In all four examples, the various aberrations are well astabilized in the front three members L<sub>1</sub>, L<sub>2</sub>. Let hroughout the range of variation of equivalent focul length of the objective and also throughout the focus that the result of the result is the result of the result in the result is the result in the

In Examples I and II, such rear member may be de- 20 scribed as of modified Cooke triplet construction wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are fol- 2" lowed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist 30 in balancing out the residual stabilized aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R so of the simple divergent component, where it can be employed for the simultaneous correction of spherical abstration and come with minimum effect on oblique aberrations

In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petrul construction. In this case, as simple components are used, the first there explain being convergent in order to give the necessary strong-convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no sighteric surface is used in the actual example given, none truture improvement in sherration correction could be achieved by incorporating such a struct

Yet unother alternative construction for the stationary rear member L, is employed in Example IV, consisting of seven simple components, the first three and the last two being convergent, and the fourth and fifth divergent. An aspheric surface is again used, in this case the front surface R<sub>a</sub> of the rearmost component.

It is often desired in practice to provide two different as ranges of variation of the equivalent focul length of the dobjective, and with the objective according to the present invention that can be certified unt in simple way by the minimum of the companion o

are given below of two alternative examples of achromatic doublet components suited to follow the component suited to follow the component suited to follow the commember L<sub>0</sub> of Example I above, FIOS. 3 and 6 respectively show these two examples of doublet component L<sub>2</sub> in position bettind the main objective, which for sinplicity is shown only in skeleton form, the front and rear surfaces only being abown for each of the four members L<sub>1</sub>, L<sub>2</sub>, L<sub>2</sub> and L<sub>3</sub> of the objective.

EXAMPLE V

	Radius	Thickness or uir separatien	Retractive more of	Abbe V sumber	E.loar diameter
5	Rp=00 Rp=-2.000 Rp=+8.000	\$c; ==0,2813 Phy=0,0781 U <sub>10</sub> =0,0500	1.70085 1.60688	14.33 44.63	Res 0.1912 Res 0.1912 Res 0.1812

EVAMPLE U

	Hadios	Thickness or air separation	Refractive Index ng	Abbe V namber	Chest disspotry
5	Russs Russ-2.0020 Hunch2.0030	8-; = 0.758) Ti: = 0.530 Di: = 0.550	1.75085 1.90692	50 75 52 51	Bet 0.6340 Bet 0.6340 Bet 0.6340

The dimensions in these two examples of achromatic doublet components are given in terms of the minimum value  $F_s$  of the equivalent focal length for the objective of Example I. In each table  $S_s$ . Thereferents the six esperaison between the rear surface  $R_{2s}$  of the stationary exam member  $L_s$  of Example I and the front sarriace  $R_{2s}$  or the stationary each member  $L_s$  of Example and the front sortine  $R_{2s}$  of the stationary one in each case consists of a convergent element in front of a divergent element.

The added doublet component  $L_v \circ E$  Example V increases the values of the equivalent focal length in the still 2.2, so that the normal range from  $F_v \circ V$  is a lattered by the doublet component into a range from 1.5 $F_v \circ V$  in  $F_v \circ V$  is a substantial of the still  $F_v \circ V$  is a formal  $F_v \circ V$ . The founder component of Example V acts to doublet the values of the equivalent focal length of Example I, thus giving a range from 2  $F_v \circ V$  is V in the doublet component is in goottien,

The back found distance from the rear surface R<sub>m</sub> of the added colorlet component 1, so the new position the added colorlet component 1, so the new position of the decide color of 1, so the new position of 1, so the second of 1, so the second of 1, so the second of 1, so the objective is the changed from 1, of 9, the addition of the doublet component rof, 60 in Example V and fit 0, in Example V and fit 0, so the second of 1, so the second of

16. If will be resilized that the addition of only an achinomatic doublet component to an already well corrected objective must necessarily result in a lower standard of aberration correction when the doublet component is in place. But the increased equivalent focal length such for a component is in place. But the increased equivalent focal length such for no high a mandard of or any against ried do not call for no high a mandard of correction obtained with the doublet only the objective is used alone, and for many practical purposes the standard of correction obtained with the doublet of the objective is used alone, and for many practical purposes the standard of correction obtained with the doublet of the objective is used alone, and for many practical purposes the standard of correction obtained with the doublet of the objective is used alone, and for many practical purposes the standard of correction obtained with the doublet of the objective is used alone.

blet component added is adequate. The necessary axial movement of the second and third members may be brought about in various wave for example by means of two appropriately shaped cams, which may be in the form of cam grooves B and E on the inner surface of a tubular member C rotated by the zoom control element G and surrounding the cond and third members M and H, which are held against rotation relatively to the fixed casing F of the objective. The focussing movement of the front mem- 10 but P may be effected under the control of a focusting control element O by mounting the front member in screw threaded engagement with the fixed casing F of the objective.

It will be appreciated that the foregoing examples 15 have been given by way of example only and that the invention can be carried into practice in other ways.

We claim

1. An optical objective of the zoom type (that is of the type having relatively moveble members whereby tinuously varied throughout a range, whilst maintaining constant position of the image plane), corrected for spherical and chromatic aberrations, come, astigmatism, field curvature and distortion, said objective having a maximum equivalent focal length at least 6 times its minimum focal length, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an Ju axially movable divergent second member behind the first member having equivalent focal length fa lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range 35 of variation, an axially movable divergent third member behind the second member having equivalent focal length fo lying numerically between 5 and 10 times the mum value of such ratio, a stationary convergent fourth member behind the third member, a zoom con- 40 trol element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5f, and 2.5f, and the 45 total axial movement of the third member in the range lies numerically between 0.25fc and 0.5fc, the min mum axial separation between the second and third member occurring when the equivalent focal length of the objective is greater than half its maximum value in 50 the range of variation, the movable divergent second member consisting of a divergent simple maniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member 35 consisting of a doublet component having its front surface concave to the fenny

2. An optical objective as claimed in claim 1, in which the compound component in the divergent mov-shie second member includes at least one convergent element and at least one divergent element made of materials of differing Abbe V numbers.

3. An optical objective as claimed in claim 2, in which the front surface of the compound component of 65 the second member is concave to the front and the rear surface of such component is convex to the front

4. An optical objective as claimed in claim 3, in

16 which the compound component of the second member consists of a triplet component having a convergent

element between two divergent elements. 5. An optical objective as claimed in claim 4, in which the doublet component constituting the third member has a collective internal contact convex to the

6. An optical objective as claimed in claim 2, in

which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front. 7. An optical objective as claimed in claim 2, in

which the doublet component constituting the third member has a collective internal contact convex to the front, and the materials of the two elements of such component having differing Abbe V numbers and differing mean refractive indices.

8. An optical objective as claimed in claim I, is which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front

9. An optical objective as claimed in claim 8, in which the compound component of the second member consists of a triplet component having a convergent clament between two divergent elements, the materials of all the elements of the second member having mean refractive indices greater than 1.69 and being such that the arithmetic mean between the Abbe V numbers of the materials of the divergent elements exceeds that of the convergent element.

16. An optical objective as claimed in claim 9, iscluding an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

11. An optical objective as claimed is claim 1, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

12. An optical objective as claimed in claim 11, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature substantially equal to 0.72fc, the materials of the two elements of such component having Abbe V numbers which differ by about 30 and mean refractive indices which are each greater than 1.69 and differ by about 8.09.

13. An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature substantially equal to 0.72%, the difference between the mean refractive indices of the materials of the two elements of such component being about 0.09, while the difference between the Abba V numbers of such materials is about 30.

14. An optical objective as claimed in claim 13, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

15. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining

constant position of the image plane), corrected for spherical and chromatic aberrations, come, astigmutism, field curvature and distortion, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative 5 movements, an axially movable divergent second member behind the first member having equivalent focal length fo lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the 10 objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length fc lying numerically between 5 and 10 times the minimum value of such ratio a stationary convergent fourth member behind the 15 third member, a zoom control element, and means whereby operation of the zoom control causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5fp and 29 2.5fp and the total axial movement of the third member in the range lies numerically between 0.25fc and 0.3fc. the minimum axial separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum 25 value in the range of variation, the movable divergent second member consisting of a divergent simple menia cus component with its surfaces convex to the front and a divergent compound component behind such simple component, the movable divergent third member consisting of a doublet component having its front surface concave to the front, and the first member of the objective comprises a meniscus doublet component having a front surface which is concave to the front and two simple convergent components behind such meniscus 35 which the internal contect of the meniscus doublet doublet composent.

16. An optical objective as claimed in claim 15, in which the internal contact of the meniscus doublet component of the first member is dispersive and conyex to the front.

17. An optical objective as claimed in claim 16, in which the compound component in the divergent movable second member includes at least one convergent element and at least one divergent element, and the doublet component constituting the third member has

a collective internal contact convex to the front 18. An optical objective as claimed in claim 15, in

which the two simple components of the first member together have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being greater than twice the radius of curvature of the front surface of the second of such simple components, the rear surface of the secand of the two simple components being convex to the front

19. An optical objective as claimed in claim 15, in which the axial thickness of the meniscus doublet component of the first member is is greater than the sum of the axial thicknesses of the two simple components of the first member.

26. An optical objective as claimed in claim 19, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

21. An optical objective as claimed in claim 15, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation. 22. An optical objective as claimed in claim 21, in

component of the first member is dispersive and convex to the front with radius of curvature substantially equal to 2.04f4, the difference between the mean refractive indices of the materials of the two elements of 40 the doublet being substantially 0.27.

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# UNITED STATES PATENT OFFICE CERTIFICATE OF CORRECTION

Patent No.	3,736,048		Dated Ma	7 29, 197	3	
Inventor(s)	SORDON HENRY	COOK and	PETER ARN	OLD MERIG	OLD	
It is c	ertified that er d Letters Patent	ror appears	in the abov	e-identifi	ed patent	
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[30] Sent.	Foreign Appl: 14, 1962	Creat Br	riority Da itain	ta 3508	88	
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FORM PO-1080 (10-69)



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TO ALL WHOM IT MAY CONCERN:

Be it known that we, Gordon Henry Gook and Peter Arnold Werigold, Subjects of the Gueen of England, and residents of Cadby, County of Leicester, England, and Frestatyn, County of Flintshire, Wales, United Kingdom respectively, have invented certain new and useful improvements in Optical Objectives of Variable Equivalent Focal Length, of which the following is a specification:-

#### TITLE OF THE INVENTION

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# OFTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGT: ABSTRACT OF THE DISCLOSURE

A soom lens having an improved scoming range and comprising a convergent first member which for a given object distance remains stationary during the scoming relative movements, an axially moveble divergent second member behind the first member having equivalent focal length  $\underline{f}_{\mathbb{R}}$  lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an Exially moveble divergent third member behind the second member having equivalent focal length fo lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the goom control element causes the gooming relative movements to be diffected, wherein the total axial movement of the second member in the range of variation lies numerically between  $1.5\underline{f}_{\mathrm{R}}$  and  $2.5\underline{f}_{\mathrm{R}}$  and the total axial movement of the third member in the range lies numerically between  $0.25\underline{r}_{cl}$  and  $0.5\underline{r}_{cl}$ , the minimum axial separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component. and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between  $0.5 f_{\odot}$  and  $1.0 f_{\odot}$ .

### BACKGROUND TO THE INVENTION

This application is a continuation-in-part of our prior application Serial No. 309,208, filed

mber 16, 1963 This invention relates to an optical objective

of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image glane, whereby the scale of the image can be varied, the objective being corrected for apherical and chromatic aberration, come, satigmatism, field curvature and distortion. In this type of objective, accommodation for change of object position is beusally achieved by imparting a movement, independent of the zooming relative movements, to the front member of the objective.

Many difficulties arise in the design of such objectives, and one of the problems facing designers of today is to schieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this have usually involved the use of relatively complicated movable members in the objective in order to make it possible to stabilise the aberrations throughout the range of variation, such stabilized

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aberrations then being compensated in a stat:onary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the zoom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions or have introduced too severe optical difficulties in achieving aberration correction.

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one way of reducing the mechanical complexities is so to arronge the system that the front member does not participate in the zooming movements for varying the equivalent focal length, so that this member is concerned only with focusing movements and is relieved of the complication of superimposing focusing movements on zooming movements. Such an arrangement is utilised in the present invention, wherein the primary object is to provide an improved arrangement of the movable zooming system of the objective, which can be employed with various different arrangements of the front member and

will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the envivalent focal length of the objective. BRIEF SUMMARY OF THE INVENTION

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The optical objective of the zoom type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative movements, the second and third are divergent and movable, and the fourth is convergent and stationary. the minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths  $\underline{f}_{B}$  and  $\underline{f}_{C}$  respectively of the movable second and third members lie numerically respectively between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the objective to the f-sumber of the objective in the range of variation and between 5 and 10 times such minimum ratio, the divergent movable second member consisting of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent compound component and performing Suring the range of variation a total axial movement lying numerically between 1.5fm and 2.5fm, whilst the divergent movable third member consists of a doublet component having a front surface concave to the front with radius of curvature lying numerically between 0.5f. and 1.0f and performs during the range of variation a total axial movement lying numerically between 0.25f.

and 0.5fc.

as showe described will be given later on in this specification, and a table will be found after the first example, together with an accompanying explanation showing the effect of varying those persenters for which ranges of variation are given in the preceding jurg graph within the ranges specified in that paragraph.

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It is to be understood that the terms "front" rand "reer", as used herein, relate respectively to the sides of the objective measure to and further from the longer conjugate in accordance with the usual convention.

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In addition, the term "total axial movement" is used to refer to the total distance moved by a member during zooming from one and of the range to the other, independently of the direction of movement. Thus, a member may move forward and then back during the range of variation, and in this case the total axial movement is the numerical sum of the forward distance moved plus the rearrand distance moved.

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It should also be made clear that the term "internal contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the srithmetic mean between the radii of curvature of the individual contacting surfaces, whilst the optical

power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall dimensions of the objective as small as possible and achieving the best compromise between the dismeters and the relative apartures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as for forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures of the individual members, and at the same time to assist towards the desired stabilization of the aberrations. especially of spherical aberration and come, throughout a widely extended range of variation of the equivalent focal length of the objective.

FURTHER FEATURES OF THE INVENTION

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbe V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilisation of astigmatism and distortion, the radius of curvature of

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the front surface of the simple meniscus component of the second member preferably lies numerically between  $1.5f_{\rm B}$  and  $3f_{\rm B}$ , and further assistance towards stabilization of estignatism can be obtained by arranging for the radius of curvature of the rear surface of such component to lie numerically between  $0.66f_{\rm B}$  and  $1.0f_{\rm B}$ .

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature lying numerically between 1.52 and 32s, the rear surface of such component being source to the front with radius of curvature lying numerically between 32s and 62s, thus assisting towards stabilization of spherical abetration and come.

Whilst such compound component may consist of a doublet commonent, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elemente. This, in view of the limited availability of suitable materials for the various elemente, facilitates correction of chromatic aberration and the desired stabilitetion of the other aberrations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one snother by more than 0.15. The arithmetic mean between the

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Abbe V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

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The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature lying numerically between 0.5% and %, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25. These features contribute towards the desired stabilization of spherical aberration and come and also facilitate individual correction of the third member for chargestic shermation.

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As in the case of the second member, it is preferable to employ materials for the elements of the third member having mean refractive indices greater than 1.65, in order to avoid excessive surface curvatures and thus facilitate the attainment of a wide relative aperture for the member.

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A moveble system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially edwantageous for such member to have one or more of the following characteristics:

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) The first member is preferably convergent and

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may comprise a front meniscua doublet component with its front and rear surfaces concave to the front followed by two simple convergent components, the front surface of the doublet component having dispersive optical power lying numerically between 0.5/f, and 1.0/f, where  $f_A$ is the equivalent focal length of the first member." These features permit the rear nodal point of the first member to be far to the rear and preferably behind the rear surface of the member, for cooperation with the forwardly located front nodal point of the second member. The internal contact of the meniscus doublet component of the first member may be dispersive and convex to the front with radius of curvature between  $1.5\underline{f}_{A}$  and  $3\underline{f}_{A}$ , the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15. features contribute towards stabilization of spherical aberration and astigmetism over the desired focussing range to suit different object distances. The two simple components of the first member

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may together have a combined equivalent focal length between 0.751, and 1.251, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than 11, and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than 0.751. These features assist towards stabilifying the aberrations, especially spherical sherration and astigmatism, not only throughout the

renge of focuseing adjustments, but also throughout the range of variation of ecutvalent focal length.

D) The rear surface of the rear component of the first member may be convex to the front with radius of curvature between 2LA and 7LA. This feature contributes towards stabilization of primary astigmatism throughout the range of focuseing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

The sxial thickness of the menicous doublet component of the first member may be less than 0.25% and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than 0.075%. These features contribute towards the dealered resummed location of the rear nodal point of the first member.

The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member may exceed by at least 20 the Abbe V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

The equivalent focal length  $f_{A}$  of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the contivalent focal length of the objective to the f-number of the objective. This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

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If desired, an achromatic doublet component may be provided, which can be placed at will behind the rear member of the objective to increase the value of the ensivalent focal length of the objective by a chosen ratio throughout the range of variation.

In all the arrangements according to the present invention, it is preferable for the Iris disphragm of the objective to be stationary and to be located behind the movable third member of the objective.

# DESCRIPTION OF EMBODIMENTS

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Some convenient practical examples of zoom objective according to the invention are illustrated diagrammatically in the accompanying drawings, in which (Figure 1 1 4 respectively illustrate four examples (Figure 4 being on half the scale of Figures 1 1, 3),

Figures 5 7 5 show the example of Figure 1 (in skeleton form) modified by the addition respectively of two alternative constructions of achromatic doublet component detachably mounted behind the rear member of the objective, and

Figure 7 is an axial section through a lens mount having suitable zoom control element for use in carrying out the invention.

Numerical data for these six examples are given in the following tables (numbered correspondingly to the figures of the drawings), in which R<sub>1</sub>, R<sub>2</sub>, designate the radii of curvature of the individual curraces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and

the negative sign that it is concave thereto, D<sub>1</sub>, D<sub>2,...,</sub> designate the axial thicknesses of the individual elements of the objective, and S<sub>1</sub>, S<sub>2,...,</sub> designate the axial air separations between the components of the objective. The Lables also give the mean refractive indices p<sub>3</sub> for the g-line of the spectrum and the Abbe V numbers of the materials from which the various elements of the objective are made, and in addition the clear dismeters of the various surfaces of the objective of the objective.

The second section of each table gives the values of the three variable axial air seperations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value F, to its maximum value F, are also given, together with the corresponding values of log F.

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of F.

Some of the tables also have a third section giving the sountion defining an axial section through an aspheric surface provided in the stationary rear member of the objective, the radius of curvature given for such surface in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms

The insertion of scauls (=) signs in the radius columns of the tables, in company with glus (+) and minus (-) signs which indicate whether the surface is convex or concave to the front, is for conformity with the usual Patent Office custom, and it is to be understood

that these signs are not to be interpreted wholly in their mathematical significance. This sign convention agrees with the mathematical sign convention required for the computation of some of the aberrations including the primary aberrations, but different mathematical sign conventions are required for other purposes including computation of some of the secondary aberrations, so that a radius indicated for example as positive in the tables may have to be treated as negative for some calculations as is well understood in the art.

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Redius	Thickness or Air Separation	Refractiva Index <u>n</u>	Abbe V Number	Olear Diameter
R <sub>1 = - 5.0480</sub>	D, = 0.1410	L•7847	26.10	8 <sub>1</sub> 3.4435 8 <sub>2</sub> 3.4750
2 <sub>2</sub> = + 9.0761 2 <sub>4</sub> = - 4.0991	D <sub>e</sub> = 0.6250	1.51507	56.35	R <sub>2</sub> 3.4870
3 1 <sub>4</sub> = + 11.3638	0 <sub>1</sub> = 0.0031			R <sub>4</sub> 3.3715
3 <sub>5</sub> = - 15.7510		1.717	47.90	R <sub>5</sub> 3.3610
R <sub>6</sub> = + 3.922L		1.717	47.90	ж <sub>б</sub> 3.1035
R <sub>7</sub> = + 17.1609	$S_2 = variable$			8, 3.0707
R <sub>S</sub> = + 2.7753 R <sub>c</sub> = + 1.2156	D <sub>B</sub> = 0.0563	1.69734	56.19	R <sub>8</sub> 1.7000 R <sub>9</sub> 1.4812
i <sub>9</sub> = + 1.215i i <sub>10</sub> = - 2.739i	8 <sub>4</sub> = 0.3625			R <sub>10</sub> 1.471
10 R <sub>11</sub> = + 3.1121	D <sub>6</sub> = 0.0500	1.69734 1.7847	56.19 26.10	N <sub>11</sub> 1.4.09:
R <sub>12</sub> = ~ 3.1121		1.69734	56.19	R <sub>12</sub> 1.394
13 = + 5.780	l varisble			R <sub>13</sub> 1.341;
3 <sub>14</sub> = - 1.3023 3 <sub>1,0</sub> = + 1.3023	D_ = 0.0375	1.65734	56.19	R <sub>14</sub> 0.7807
1 <sub>15</sub> = + 1.302 1 <sub>16</sub> = + 9.889	n <sub>10</sub> ≈ 0.1063	1.7847	26.10	R <sub>16</sub> 0.8300
10 R <sub>17</sub> = + 13.8889 R <sub>18</sub> = - 1.8116	5 11 = 0.1250	1.524	58.87	R <sub>17</sub> 0.8865 R <sub>18</sub> 0.9017
R <sub>19</sub> = + 1.8116 R <sub>20</sub> = - 8.3333	D <sub>12</sub> = 0.1250	1.524	53.87	H <sub>19</sub> 0.9157 H <sub>20</sub> 0.9108
21 = + 1.041	D <sub>1 2</sub> ≈ 0.1250	1.524	58.87	R <sub>21</sub> 0.8858
t <sub>22</sub> = + 3.1250 t <sub>23</sub> = - 4.0770	Sc = 0.2373	1.7283	28.66	R <sub>22</sub> 0.860;
k <sub>24</sub> = + 1.0620 k <sub>25</sub> = + 5.1589	s <sub>10</sub> = 0.3175		-0.66	R <sub>24</sub> 0.690 R <sub>25</sub> 0.719
25 i <sub>26</sub> = + 1.500 i <sub>27</sub> = - 1.500	D <sub>1</sub> ≥ 0.1563	1.7283 1.61452	28.66 56.22	8 <sub>26</sub> 0.7200 8 <sub>27</sub> 0.7225

A	s <sub>3</sub>	TD B5	TE 85 -	TF P	16 log F
	0.03023	2.544.23	0.68858	1.00000	0.00
	1.11409	1.40738	0.74157	1.77827	0.25
	1.93430	0.60333	0.72521	5.16227	0.50
	2.55076	0.16104	0.55123	5.62339	0.75
	2.96233	0.16657	0.13414	10.00000	1.00
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Equation for aspheric surface Rgx

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The foregoing Example describes a complete thick lens design, with values calculated in many cases to the fourth decimal place, and several additional Examples of this type will be given subsequently.

It is, however, obviously impractical to provide such fully calculated thick lens designs for values broadly distributed throughout the previously specified ranges for all the significant parameters.

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However, in order to show the effect of altering the principal parameters within the ranges specified for those parameters, and demonstrate the practicality of designing lenses having paremeter values near the extremes of the specified ranges, an illustrative table is given below. The parameters given are all thin lens parameters (parameters of the thin lens construction on which Example I is based) and the effects of these parameter variations

are shown on the dimensions of the overall objective and the relative apertures ( $\underline{f}$ -numbers) of the first three members.

In the following table:

F<sub>B</sub> is the focal length of the second member;

fF<sub>B</sub> is the focal length of the third member;

fF<sub>C</sub> is the total axial movement of the second member;

T<sub>C</sub> is the total exial movement of the third member;

R is the minimum value of the ratio of the focal

length of the complete objective to its f\_number;
-L is the overall length from the front of the
objective to the focal plane;

D is the maximum dismeter at the front of the objective;

 $F_{\rm N1} \ \ {\rm is \ the \ relative \ aperture \ of \ the \ first \ member;}$   $F_{\rm N2} \ \ {\rm is \ the \ relative \ aperture \ of \ the \ third \ member.}$ 

The four critical thin lens parameters set forth in the fifth paragraph of this specification and in the main claim are  $F_B$ ,  $F_C$ ,  $T_B$ , and  $T_C$ , and their values for Example I are shown in line 1 of the table. In line 2,  $F_B$  is put should to the lower limit (4A) of the main claim, and in line 3 equal to the upper limit (8A). In lines 4 and 5  $F_C$  is treated similarly.  $T_B$  and  $T_C$  are dealt with in similar manner in lines 6 and 7 and lines 8 and 9. It is not possible to very the four parameters completely independently of one another (this is referred to again later), and in fact when one parameter is set to an end limit, at least two of the others have been adjusted, in the table, so that the range of variation of

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focal length remains approximately unchanged.

1		FB	$F_{\bar{G}}$	TB	T <sub>C</sub>	L	D	FNL	) N2	P <sub>N3</sub>
1	Example 1	-1.47	-1.82	2.93	0.66	3.62	2.81	1.59	1.0	2.29
2	Fg-1.0 (4R)		-1.82							
3	F <sub>B</sub> -2.0 (8R)	-2.0	-1.82	3.50	0.79	4.30	3.12	1.74	1.04	2.39
ė,	F <sub>C</sub> -1.25 (5R)	-1.47	-1.25	2.44	0.58	3.11	2.69	1.40	1.00	1.67
5	F <sub>O</sub> -2.5 (10%)	-1.47	-2.50	3.38	0.77	4.07	2.94	1.74	0.98	3.07
6	T32.5 (2.5FB)	-1.0	-2.36	2.50	0.66	3.18	2.62	1.44	0.91	2.78
7	TB3.0 (1.5FB)	-2.0	-1.26	3.00	0.69	3.58	2.87	1.54	1.06	1.76
8	Tc0.68 (0.27Fc)	-1.0	-2.50	2.57	0.68	3.24	2.69	1.46	0.91	2.94
9	T <sub>C</sub> 0.72 (0.5F <sub>C</sub> )	-2.0	-1.44	3.22	0.72	3.91	3.00	1.63	1.05	1.97

a grample I is a zoom lens intended for construction to a medium dimensional scale to cover average format dimensions.

In line 2, the effect of putting  $\boldsymbol{F}_{\underline{B}}$  to its lower limit is to reduce L and D. Fn1, Fno and Fna are also reduced, meaning that each individual member has a wider relative sperture. Because of their wider relative apertures, these members would have to be more complex (contain more usable thick lens peremeters) than they are 10 in Example I, in order to achieve the same high standard of aberration correction. However, this greater complexity would be acceptable for a goom objective built to a small dimensional acale covering small image format dimensions. Such a small scale construction would readily be possible in view of the reductions in 15 L and D. Therefore, a goom lene within the scope of the main claim, with  $P_n$  at or near its lower limit, would be preferred for a lens of wider relative sperture

but constructed to a smaller dimensional scale than Example I.

Line 3 shows the effect of putting  $F_3$  to its upper limit. Conversely, from the changes in L, D,  $F_{N1}$ ,  $F_{N2}$  and  $F_{N3}$ , it can be seen that such a modified thin lens construction would be suitable for development of a final objective of relatively single construction constructed to cover relatively large image format dimensions (at which scale high complexity would not be permissible) at a smaller relative aperture than Example I.

. Lines h and 5 show identical effects achievable by putting  $S_{ci}$  of its fower and upper limits.

Line 6 shows the effect of putting the total exist ocvement of the second member at its upper limit. In fact, in order to do this, it is necessary to put at least either  $\mathbb{F}_{n}$  or  $\mathbb{F}_{n}$  at or near its end limit. This is dictated by the fundamental laws of optics, also bearing in mind the requirement to keep the focal range roughly the same. However, the effect is now not noite the same as in lines 3 to 5, because one axial movement now slso lies at its end limit. Thus, the change in L and D from Example I is reduced, while the relative aperture of one member (the third member) is increased but the other two are reduced. Lines 7 to 9 show similar effects; in extent from Example I, as also are Png,  $\mathbf{F}_{N2}$  and  $\mathbf{F}_{N3}$  . Reverting to line 6 in particular, this modification is suited to a moderately small but not extremely small dimensional scale of final objective having a medium relative aperture, wherein the smaller

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relative sperture of the third member either permits its complexity to be reduced or, more usefully, its existing complexity utilised to achieve an extremely high standard of aberration correction. Corresponding but slightly different effects can be seen from the modifications of lines 7 to 9.

In general therefore, it can readily be seen from the table how the perameters of the main claim can be taken to their end limits to provide differing effects suited to differing initial requirements. The lens designer given the main claim and having a particular end requirement can work accordingly.

The table also demonstrates the sense of the end limits. For example, to take Fg below the value of 1.0(4R) in line 2 would be further to decrease L and D and further widen the relative apertures of the second. third and fourth members. Obviously a cuestion of opinion is involved at this point, but the opinion of the inventor is that the complexity of construction for the second to fourth members, in order to achieve good aberration correction at the further widened relative aperture, would render a practical construction a noncommercial proposition. Likewise to take  $\mathbb{F}_{\mathfrak{R}}$  beyond the value of 2,0(8R) in line 3 would only permit construction of a practical corrected objective to such a large dimensional scale that it would find no useful application. The same factors also arise in the modifications of lines 5 to 9, when coupled with the requirement to maintain a large range of variation of focal length, which is an essential object of the invention.

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Radius	Thickness or Refract Air Separation ladex	tive Abbe V n <sub>d</sub> Number	Clear Diameter
R <sub>1</sub> = - 7.2114	D, = 0.2014 1.7847	7 26.10	R <sub>1</sub> 4.9192
$R_2 = +12.9661$ $R_3 = -5.8567$	D <sub>2</sub> = 0.8928 1.5150	07 56•35	R <sub>2</sub> 4.9642 R <sub>3</sub> 4.9814
R <sub>L</sub> = + 16.2336	5 <sub>1</sub> = 0.0045 D <sub>3</sub> = 0.3651 1.7170	47.90	R <sub>4</sub> 4.8164
$R_5 = -22.5012$ $R_6 = +5.6034$	S <sub>2</sub> = 0.0045	3 179 (23	R <sub>5</sub> 4.8014 R <sub>6</sub> 4.4335
R <sub>7</sub> = + 24.5154	$D_{i_1} = 0.4241 - 1.7170$ $S_3 = \text{variable}$	3 47.99	R <sub>7</sub> 4.3867
8 <sub>8</sub> = + 3.9647 8 <sub>9</sub> = + 1.7362	D <sub>5</sub> = 0.0804 1.6973	34 56 <b>.</b> 19	R <sub>g</sub> 2.4,286
R <sub>10</sub> = - 3.9138 R. = + 4.8458	s <sub>h</sub> = 0.5178 s <sub>6</sub> = 0.071h 1.6973	54 56.19	R <sub>10</sub> 2.1018
R <sub>11</sub> = + 4.4458 R <sub>12</sub> = - 4.4458	0 <sub>7</sub> = 0.3036 1.7647 0 <sub>8</sub> = 0.0714 1.6973		H <sub>11</sub> 2.0132
H <sub>13</sub> = + 8.2572 R., = - 1.8601	S <sub>5</sub> = variable		R <sub>13</sub> 1.9161 R <sub>14</sub> 1.1153
R <sub>14</sub> = - 1.8601 R <sub>15</sub> = + 1.8601	D <sub>9</sub> = 0.0536 1.6973		H <sub>15</sub> 1.1721
R <sub>16</sub> = + 14.1274 R <sub>17</sub> = - 10.0095	Sg = variable		8 <sub>16</sub> 1.1857 R <sub>17</sub> 1.2552
R <sub>18</sub> = - 1.9192	D <sub>11</sub> = 0.1875 1.5168 S <sub>7</sub> = 0.0045	š 64.20	* <sub>18</sub> 1.2861
R <sub>19</sub> = + 2.6841 R <sub>20</sub> = - 10.8725	D <sub>12</sub> = 0.1875 1.5168	64.20	R <sub>19</sub> 1.3110 R <sub>20</sub> 1.3033
R <sub>21 = + 1.3446</sub>	\$ <sub>8</sub> = 0.0045 D <sub>13</sub> = 0.1875 1.5168	3 64.20	R <sub>21</sub> 1.2672
R <sub>22</sub> = +. 2.9064 R <sub>23</sub> = - 4.2315	8 <sub>9</sub> = 0.6375 (aspheric)	28.66	R <sub>22</sub> 1.2220 R <sub>23</sub> 1.0500
R <sub>24</sub> = + 1.9174 R <sub>25</sub> = ∞	D <sub>14</sub> = 0.3777 1.7283 8 <sub>10</sub> = 0.4714		* <sub>24</sub> 0.9686 * <sub>25</sub> 1.0019
<sup>2</sup> 26 = + 2.3366	D <sub>15</sub> = 0.0929 1.7283 D <sub>16</sub> = 0.2304 1.6134		R <sub>26</sub> 1.0088
R <sub>27</sub> = - 2.3366 R <sub>28</sub> = + 5.7670	S <sub>11</sub> = 0.0045		R <sub>28</sub> 1.0088
"28 = - 5.7670	D <sub>17</sub> = 0.2304 1.6134	2 59.27	R <sub>29</sub> 0.9778

(P)

S3 TD S5 TE S6 TF F TG LOS F 3.63462 0.98730 1.00000 0.00 2.01054 1.06300 1.77827 0.25 2.76329 0.86219 1.03962 3.16227 0.50 3.64395 0.79109 0.23005 5.62339 0.75 4.23190 0.23796 0.19524 10.00000 1.00

Equation for aspheric surface R<sub>23</sub>

x = -4.2315 + 17.90559 = x<sup>2</sup> - 0.01666805 x<sup>4</sup> + 0.02010843 x<sup>6</sup>
- 0.020176346 x<sup>6</sup> - 0.00553820 x<sup>10</sup>

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Redius	Thickness or Refractive Air Separation Index $\underline{p}_{\underline{d}}$	Abbe V Number	Clear Dismeter
R <sub>1</sub> = - 7.2114	D, = 0.2014 1.7847	26.10	H <sub>1</sub> 4.9192
R <sub>2</sub> = + 12.9661	0 = 0.8928 1.51507	56.35	W <sub>2</sub> 4.9642
k <sub>3</sub> = - 5.8567	8, = 0.0045		R <sub>3</sub> 4.9814
R <sub>4</sub> = + 16.2336	D, = 0.3661 1.7170	47.90	R <sub>L</sub> 4.8164
R <sub>5</sub> = - 22.5012	S <sub>m</sub> ≈ 0.0045		R <sub>5</sub> 4.6014
R <sub>6</sub> = + 5.6034	OF # O*#S81 ***/1/-	47.90	R <sub>6</sub> 4-4335
$R_7 = +24.5154$	S, = variable		R <sub>7</sub> 5.3867
Rg = + 3.9647	D <sub>5</sub> = 0.0804 1.69734	56.19	8 <sub>8</sub> 2.4286
Ry = + 1.7362	S, = 0.5176		8 <sub>5</sub> 2.1161
R <sub>10</sub> = - 3.9318	D. = 0.0714 1.69734	56.19	R <sub>10</sub> 2.1018
H <sub>13</sub> = + 4.4458	D., = 0.3036 1.7847	26.10	R <sub>11</sub> 2.0132
R <sub>12</sub> = - 4.0458	D. = 0.0714 1.69734	56.19	N <sub>12</sub> 1.9925
R <sub>13</sub> = + 8.2572	S. = variable		R <sub>13</sub> 1.9161
R <sub>14</sub> = - 1.8601	D. = 0.0536 1.69734	56.19	R <sub>1/4</sub> 1.1153
B <sub>15</sub> = + 1.8601	Dan = 0.1518 1.7847	26.10	H <sub>15</sub> 1.1721
816 = + 14.1274	S <sub>f</sub> = variable		R <sub>16</sub> 1.1857
R <sub>17</sub> = 00	D <sub>11</sub> = 0.1911 1.524	58.87	R <sub>17</sub> 1.2830
R <sub>18</sub> = - 2.3322	S <sub>m</sub> ≈ 0.0045		H <sub>18</sub> 1.3098
R <sub>19</sub> = + 10.6292	D, = 0.1910 1.524	58.87	R <sub>19</sub> 1.3238
R <sub>20</sub> = - 10.6292	S <sub>8</sub> = 0.0045		R <sub>20</sub> 1.3288
R <sub>21</sub> = + 2.7812	D <sub>13</sub> = 0.2678 1.61342	59.27	821 1.3273
R <sub>22</sub> = - 2.7812	S <sub>C</sub> = 0.0100		R <sub>22</sub> 1.3060
R <sub>23</sub> = - 2.5142		28.66	R <sub>23</sub> 1.3049
R <sub>24</sub> = 00	S <sub>10</sub> = 1.8928		R <sub>24</sub> 1.9833
R <sub>25</sub> = ~	D <sub>15</sub> = 0.0893 1.72830	28.66	R <sub>25</sub> 0.9600
R <sub>26</sub> = + 1.4266	\$15 = 0.0298		K <sub>26</sub> 0.9600
8 <sub>27</sub> = + 1.6477	D <sub>16</sub> = 0.2929 1.69734	56.19	R <sub>27</sub> 0.9600
Rog = - 2.7358	16 - 16	,,,,,,,	H <sub>28</sub> 0.9600



	CIA	s <sub>3</sub> T	<b>D</b> s <sub>5</sub> T	€ 86 T	FFT	G log P	
	1	0.04318	3.63462	1.0319	1.00000	0.00	
. ^	)	1.59156	2.01054	1.1076	1.77827	0.25	
X	1	2.76329	0.86219	1.08422	3.16227	0.50	
- ·	/ \	3.64395	0.23005	0.83569	5.62339	0.75	
		4.23190	0.23796	0.23984	10.00000	1.00	T>-
	/ L		<u> </u>	<u> </u>	<u> </u>	<u> </u>	15

	Example IV		i i
Redius	Thickness or Refra Air Separation Inde	ctive Abbe V X <u>n</u> d Sumber	Cleur Diameter
R <sub>1 = - 12.6240</sub>	D <sub>1</sub> ≈ 0.3526 1.78	47 26.10	R <sub>1</sub> 8.6115
$R_2 = + 22.6983$ $R_3 = -10.2525$	D <sub>2</sub> = 1.5630 1.519	507 56.35	R <sub>2</sub> 8.5903 R <sub>3</sub> 8.7203
R <sub>14</sub> = + 28.4181	S <sub>1</sub> = 0.0078 D <sub>2</sub> = 0.6409 1.71	70 47.90	R <sub>4</sub> 6.4314
R <sub>5</sub> = - 29.3901 R <sub>6</sub> = + 9.8091	s <sub>2</sub> = 0.0078		N <sub>5</sub> 5.4052
R <sub>7</sub> = + 42.9160	$v_{i_4} = 0.7425$ 1.71 $\varepsilon_{\chi} = \text{variable}$	70 47.90	H <sub>7</sub> 7.6792
R <sub>9</sub> = + 6.9388	D <sub>5</sub> = 0.1407 1.69	56.33	R <sub>G</sub> 4.2516
H <sub>10</sub> = - 6.8699	B <sub>L</sub> = 0.9066 D <sub>S</sub> = 0.1250 1.69	681 56.33	R <sub>10</sub> 3.6795
R <sub>11</sub> = + 7.8124 R <sub>12</sub> = - 7.8124	D <sub>7</sub> = 0.5314 1.785		H <sub>11</sub> 3.5240 H <sub>12</sub> 3.4870
R <sub>13</sub> = + 14.3312	U <sub>8</sub> = 0.1250 1.596 S <sub>z</sub> = variable	56.33	R <sub>13</sub> 3.3528
R <sub>15</sub> = - 3.2586	Dg = 0.0938 1.696		R <sub>14</sub> 1.9539 R <sub>15</sub> 2.0536
R <sub>16</sub> = + 24.3322	$D_{10} = 0.2657$ 1.789 $S_6 = \text{variable}$	503 26.09	k <sub>1,6</sub> 2.0774
$R_{17} = -12.5098$ $R_{18} = -3.7028$	D <sub>11</sub> = 0.3345 1.650	58.60	R <sub>17</sub> 2.2274 R <sub>18</sub> 2.2699
R <sub>19</sub> = + 10.5352	57 = 0.0078 5 <sub>12</sub> = 0.3345 1.650	031 58.60	R <sub>19</sub> 2.3212
R <sub>20</sub> = - 10.5352 R <sub>21</sub> = + 4.8649	\$ <sub>8</sub> = 0.0078 D., = 0.4689 1.613	517 55.27	R <sub>20</sub> 2.3181 R <sub>21</sub> 2.2837
R <sub>22</sub> = - 4.8649 R <sub>02</sub> = - 4.1260	D <sub>13</sub> = 0.4689	371 33.51	R <sub>22</sub> 2.2259
R <sub>23</sub> = - 4.1260 R <sub>24</sub> = + 27.3461	$D_{11} = 0.1563$ 1.726 $S_{10} = 2.8136$	32 28.66	R <sub>23</sub> 2.2243 R <sub>24</sub> 2.1602
R <sub>25</sub> = 00	S <sub>10</sub> = 2.8136 D <sub>15</sub> = 0.1563 1.761	128 26.98	k <sub>25</sub> 1.7178
$R_{26} = + 1.8127$ $R_{27} = + 1.8913$	S <sub>11</sub> = 0.0119 D <sub>16</sub> = 0.5643 1.650	931 58 <b>.</b> 60	*26 1.7350 k <sub>27</sub> 1.7382
R <sub>28</sub> = - 3.5367 R <sub>28</sub> = + 3.9463	S <sub>12</sub> = 0.0078 (aspheric)	54.00	R <sub>28</sub> 1.7741 R <sub>29</sub> 1.7554
R <sub>29</sub> = + 3.9463 R <sub>30</sub> = 00	b <sub>17</sub> = 0.2880 1.650	031 58 <b>.6</b> 0	k <sub>30</sub> 1.7100



	(TA	83 T	<b>6</b> s <sub>5</sub> 1	Ē 86 -	IF F T	6 108 F	
	1	0.08428	6.36327	1.80704	1.00000	5.0	
	1	2.79513	3.51989	1.93956	1.77827	0.25	
SK	<b>4</b>	4.84654	1.50941	1.89864	3.15227	0.5	
حمپ	1 1	6.38837	0.40269	1.46352	5.62339	9.75	
	1 /	7.41774	0.41652	0.42032	20.00000	1.0	P
	£	<del></del>		<u>L</u>			1

Equation for assertic surface  $R_{29}$   $x = +3.9463 - \sqrt{15.57328 - x^2} + 0.00427020 x^6$  $x = -3.9463 - \sqrt{15.57328 - x^2} + 0.00721693 x^{10}$ 

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In all these examples, the maximum value  $\boldsymbol{F}_{m}$  of the equivalent focal length F of the objective is ten times the minimum value F, thereof. Example I is corrected for a relative aperture 1/4.0, whilst Examples II and III are each corrected for a relative aperture f/2.8, and Example IV is corrected for a relative aperture of f/1.6. Examples II and III differ from one another solely in the stationary rear member L, the front three members  $\mathbf{L}_{\hat{\mathbf{A}}},~\mathbf{L}_{\hat{\mathbf{B}}}$  and  $\mathbf{L}_{\hat{\mathbf{C}}}$  being identical in the two examples. Such members  $\mathbf{L}_{\mathbf{A}},~\mathbf{L}_{\mathbf{B}}$  and  $\mathbf{L}_{\mathbf{C}}$  are in fact similar to the front three members in it and it, of Example I, the dimensions being scaled up from those of Example I in the ratio of the f-numbers, that is in the ratio of 4.0/2.8. The rear members L, in Examples II and III are, however, not scaled-up versions of the rear member  $L_n$  of Example I. The front three members  $L_{\rm A}$ ,  $L_{\rm B}$ , Ln of Example IV, which includes yet another alternative

construction of rear member  $L_{\rm D}$ , are of the same general type as those of Examples I  $_{\rm L}$  III, but their numerical dimensions differ somewhat from a version of those of Example I scaled up in the ratio 4,9/1.6.

All these examples cover a semi-angular field of view varying from 27 degrees at  $F_{\underline{\sigma}}$  to 2.7 degrees at  $F_{\underline{\sigma}}$ 

The iris disphragm in all four examples is stationary and is located between the movable third member  $L_{\rm C}$  and the stationary rear member  $L_{\rm D}$ . In Example I the disphragm is 0.0625 F<sub>0</sub> in front of the surface R<sub>17</sub> and has dismeter 0.8568 F<sub>0</sub>; in Example II the disphragm is 0.0929 F<sub>0</sub> in front of the surface X<sub>17</sub> and has dismeter 1.2240 F<sub>0</sub>; and Example III the disphragm is 0.1375 F<sub>0</sub> in front of the surface R<sub>17</sub> and has diameter 1.2240 F<sub>0</sub>; and in Example IV the disphragm is 0.2407 F<sub>0</sub> in front of the surface R<sub>17</sub> and has diameter 1.240 F<sub>0</sub>; and in Example IV the disphragm is 0.2407 F<sub>0</sub> in front of the surface R<sub>17</sub> and has diameter 2.1446 F<sub>0</sub>.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F<sub>0</sub> in Example I, 2.6761 F<sub>0</sub> in Example II. 2.3027 F<sub>0</sub> in Example III and 1.7878 F<sub>0</sub> in Example IV.

The equivalent focal length  $f_A$  of the stationary first member  $L_A$  is + 4.4551  $F_0$  in Example I, + 6.3644  $F_0$  in Example II and III and + 11.1415  $F_0$  in Example IV; the equivalent focal length  $f_B$  of the movable second member  $L_B$  is - 1.4703  $F_0$  in Example I, - 2.1004  $F_0$  in Example II and III and - 3.5770  $F_0$  in Example IV; the equivalent focal length  $f_0$  of the movable third member  $L_0$  is - 1.8176  $F_0$  in Example I, - 2.5966  $F_0$  in Example II and III and - 4.5458  $F_0$  in Example IV; and the equivalent

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focal length  $\frac{f}{10}$  of the stationary fourth member  $L_D$  is +1.4753 P<sub>0</sub> in Example I, +2.1286 F<sub>0</sub> in Example II, +2.1232 F<sub>0</sub> in Example III and +4.0419 F<sub>0</sub> in Example IV; the positive and negative signs respectively indicating convergence and divergence.

In all four examples, the convergent stationary front member  $L_{A}$  consists of a meniscus doublet component rollowed by two convergent simple components. The front surface  $R_{1}$  of the doublet component is concave to the front and has dispersive optical power numerically equal to  $0.165/F_{0}$  or  $0.692/f_{A}$  in Example I, to  $0.105/F_{0}$  or  $0.692/f_{A}$  in Examples II and III, and to  $0.062/F_{0}$  or  $0.692/f_{A}$  in Example IV. The internal contant  $R_{2}$  of the doublet component is dispersive and convex to the front and has radius of curvature equal to  $2.037 f_{A}$  in all four examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is 0.27 in all four examples. The combined equivalent focal length of the

two simple components of the first member L, is 4.0013 F<sub>0</sub> in Example I, 5.7162 F<sub>0</sub> in Examples II and III, and 10.0064 F<sub>0</sub> in Example IV or 0.8581 f<sub>A</sub> in sll four examples. The radius of curvature K<sub>1</sub> of the front surface of the first of such simple components is 2.551 f<sub>A</sub> in sll four examples, and the radius of curvature K<sub>0</sub> of the front surface of the second of such simple components is 0.860 f<sub>A</sub> in sll four examples. The rear surface R<sub>1</sub> of such second simple component is convex to the front with radius of curvature 3.852 f<sub>A</sub> in all four examples.

The axial thickness (D<sub>1</sub> + D<sub>2</sub>) of the mediacus

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doublet component of the first member L is 0.756 F<sub>0</sub> in Example II, 1.094 F<sub>0</sub> in Examples II and III, and 1.916 F<sub>0</sub> in Example IV, or 0.172 f<sub>4</sub> in all four examples. The sum of the axial thicknesses of the two simple components (D<sub>3</sub> \* D<sub>4</sub>) of the first member is 0.555 F<sub>0</sub> in Example I, 0.750 F<sub>0</sub> in Example II and III, and 1.383 F<sub>0</sub> in Example IV, or 0.124 f<sub>4</sub> in all

four examples.

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The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member L<sub>A</sub> in all four examples is 50,72 and thus exceeds the Abbe V number of the material of the divergent front element by 24,62.

The maximum value of the retio of the enuivalent focal length of the objective to the f-number of the objective is 2.5 F<sub>0</sub> in Example I, 3.57 F<sub>0</sub> in Examples II and III, and 6.25 F<sub>0</sub> in Example IV, so that in all four examples  $f_A$  is 1.782 times such maximum value.

In all four examples, the minimum separation between the movable second and third members  $L_{\rm B}$  and  $L_{\rm G}$  occurs when the equivalent focal length of the objective is 7,45  $\rm P_{\rm G}$ , and the numerical values of the equivalent focal lengths  $L_{\rm B}$  and  $\frac{f}{L_{\rm G}}$  of such members are respectively 5.86 and 7.27 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective.

The movable second member L<sub>D</sub> in all four examples consists of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent

element between two divergent elements, and its total axial movement (a unidirectional regreated movement) in the range of variation is numerically equal to 1.994  $\Sigma_{\mathrm{B}^{\bullet}}$ The front and rear surfaces kg and Ry of the simple meniscus component of such member respectively have radii of curvature numerically equal to 1.89  $\underline{\mathbf{f}}_{\mathrm{B}}$  and 1.83  $\underline{\mathbf{f}}_{\mathrm{B}}$  in ell four examples, whilst the front and rear sarfaces kan and  $\Re_{13}$  of the triplet component respectively have radii of curvature numerically equal to 1.85  $\underline{f}_{2}$  in Examples I | III and  $1.87 \pm 8$  in Example IV and to  $3.93 \pm 8$  in Exemples I  $\frac{1}{4}$  III and 3.99  $f_B$  in Example IV.

The moveble third member Lo in all four examples consists of a doublet component, whose front surface R 14 is concave to the front with radius of curvature numerically equal to  $0.72 \pm 0$ , and the total axial movement (the numerical sum of an initial forward movement plus a subsequent rearward movement) of such member is numerically equal to 0.363  $\underline{f}_{3}$ . The internal contact Ris of such doublet component is collective and convex to the front, with radius of curvature numerically equal to 0.72  $f_G$ . The difference between the mean refractive indices of the materials of such doublet component is 0.087 in Examples I 1 III and 0.088 in Example IV, the difference between their Abbe V numbers being 30,09 in Examples I  $\uparrow$  III and 30,24 in Example IV. In all four examples, the various aberrations

are well stabilized in the front three members LA, LB, LC throughout the range of variation of equivalent focal length of the objective and also throughout the focussing

range, and the stationary rear member  $L_{\mathrm{D}}$  serves to balance

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out such residual stabilized aberration, and also to locate the resultant image plane in a convenient position. The construction of such rear member may thus very widely.

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In Exemples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the atrong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilised aberrations of the front three members without undue increase in the overall length of the objective, such aspheric gurface being the front surface  $R_{24}$  of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and come with minimum effect on oblique aberrations.

In Example III, a comewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no appheric surface is used in the actual example given,

some further improvement in aberration correction could be achieved by incorporating such a surface.

Yet snother alternative construction for the stationary reer member  $L_{\rm D}$  is employed in Example IV, concisting of seven simple components, the first three and the last two being convergent, and the fourth and fifth divergent. An aspheric surface is again used, in this case the front surface  $E_{\rm Zy}$  of the restmost component.

It is ofsen desired in practice to provide two

different ranges of variation of the enginelent focal length of the objective, and with the objective according to the present invention this can be carried out in a simple way by the provision of an achromatic doublet component, which can be placed at will behind the stationary rear member L, of the objective, such doublet component, when in position, acting to move the resultant image plane further from the rear surface of the member In and to increase the values of the engivelent focal length of the objective in the same proportion throughout the range. Another effect of the addition of this doublet component is to reduce the relative aperture of the objective and the angular field covered. Sumerical data are given below of two alternative examples of schromatic doublet component suited to follow the rear member L, of Example I above. Figures 5 and 6 respectively show these two examples of doublet component L, in position behind the main objective. which for simplicity is shown only in skeleton form, the front and rear surfaces only being shown for each of the four members L, L, L, and L, of the objective.

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	Example V			1
Radius	Thickness or air Jeparation	Refractive Index <u>n</u> d	Abbe V Number	Clear Diameter
Ř <sub>28</sub> ≈ ∞	S <sub>11</sub> = 0.2812 D <sub>17</sub> = 5.0781	1,70035	30.28	R <sub>28</sub> 0.7312
R <sub>29</sub> = - 2.0920 R <sub>30</sub> = + 3.3428	D <sub>18</sub> = 0.0500	1.60483	43.83	H <sub>29</sub> 0.7312 H <sub>30</sub> 0.7312

	Example VI			
Redius	Thickness or Air Separation	Refractive Index <u>n</u> d	Abbe V Number	Clear Diameter
	s <sub>11</sub> = 0.7365			
8 <sub>28</sub> = 00	D <sub>17</sub> = 0.0781	1.70035	5U a < 0	R <sub>28</sub> 0.6749
R <sub>29</sub> = - 2.0920	D <sub>18</sub> = 0.0500	1.60982		H <sub>29</sub> 0.6749
R <sub>30</sub> = + 2.0920	10			830 0.6749

The dimensions in these two examples of schromatic doublet component are given in terms of the minimum value  $\mathbb{F}_0$  of the emissions found length for the objective of Example I. In each table  $S_{11}$  represents the air separation between the rear surface  $\mathbb{S}_{27}$  of the stationary rear member  $\mathbb{L}_0$  of Example I and the front surface  $\mathbb{S}_{28}$  of the added doublet component. The doublet component in each case consists of a convergent element in front of a divergent element.

The edded doublet component  $L_g$  of Example V increases the values of the equivalent focal length in the ratio 1:2, so that the normal range from  $P_0$  to 10  $F_0$  is altered by the doublet component into a range from 1.5  $F_0$  to 15  $P_0$ . The doublet component of Symmple VI acts to double the values of the equivalent focal length of

Example I, thus giving a range from 2 P to 20 Po when the doublet component is in position.

The back focal distance from the rear surface  $\kappa_{30}$  of the added doublet component  $L_{8}$  to the new position of the resultant immse plane is 3.70%  $F_{0}$  in Example V and 4.028  $F_{0}$  in Example VI. The relative exerture of the objective is changed from f/4.0 by the addition of the doublet component to f/6.0 in Example V and f/8.0 in Example VI. The semi-angular field, which for Example 1 alone varies from 27 degrees at  $F_{0}$  to 2.7 degrees at  $F_{m}$ , varies (when the doublet component of Example VI is added) from 18 degrees at 1.5  $F_{0}$  to 1.8 degrees at 15  $F_{0}$ , and (when the doublet component of Example VI is added) from 13.5 degrees at 2. $F_{0}$  to 1.35 degrees at 2.0  $F_{0}$ 

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It will be realised that the addition of only an achromatic doublet component to an already well-corrected objective must necessarily result to a lower standard of aberration correction when the doublet component is in place. But the increased equivalent focal length and reduced relative aperture and angular field do not call for so high a standard of correction as is needed when the objective is used alone, and for many practical surposes the standard of correction obtained with the doublet component added is adequate.

The necessary exial movement of the second and third members may be brought about in various ways, for example by means of two appropriately shaped cama, which may be in the form of cam grooves B and B on the inner surface of a tubular member C rotated by the moon

control element 0 and surrounding the second and third members M and H, which are held against rotation relatively to the fixed casing F of the objective. The focussing movement of the front member P may be affected under the control of a focusing control element O by mounting the front member in screw threaded engagement with the fixed casing F of the objective.

It will be apprecisted that the foregoing examples have been given by way of example only and that the invention can be carried into practice in other ways.

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An optical objective of the zoom type (that is of the type having relatively moveble members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane), corrected for apherical and chromatic aberrations, come, astigmatism, field curvature and distortion, said objective having a maximum equivalent focal length at least six times its minimum focal length, and comprising a convergent first member which for a given object distance remains stationary during the gooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length  $\underline{f}_{\mathrm{R}}$  lying numerically between a and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective is the range of variation, an axially movable divergent third member behind the second member having equivalent focal length fo lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5fm and  $2.5\underline{f}_{\mathrm{B}}$  and the total axisl movement of the third member in the range lies numerically between 0.25 $\underline{r}_0$  and 0.5 $\underline{r}_0$ , the minimum axial separation between the second and third member occurring when the equivalent focal length of the

range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the moveble divergent third member consisting of a doublet component having its front surface concave to the front, with radius ture lying numerically between 0.5f. and 1.0f. An optical objective as claimed in claim 1, in which the compound component in the divergent movable second member includes at least one convergent element at least one divergent element made of materials V numbers &tiller by more than 25. An optical objective as claimed in claim 2, in which the radii of curvature of the front and rear surfaces of the simple meriacus component of the second member respectively lie numerically between 1.51 and  $3f_{\rm p}$  and between  $0.66f_{\rm p}$  and  $f_{\rm p}$ . An optical objective as claimed in claim of in which the front surface of the compound component of the second member is concave to the front wi curvature lying numerically between 1.5ft, and 3f., the rear surface of such component is convex to the front. radius of curvature lying numerically between if. An optical objective as claimed in claim . in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements the untertals of the

objective is greater than helf its maximum value in the

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by less than 0.15 from one eacther, the materials of all the elements of the second member having mean refractive indices greater than 1.65 for design such that the arithmetic mean between the Abre V members of the materials of the divergent elements exceeds that of the convergent element by at least 25.

An optical objective as claimed in claim. In which the doublet component constituting the third sember has a collective internal contect convex to the front.

The radius of curvature lying numerically between 0.555 and for the actorials of the two elements of such component having Abbe V natury which differ by more than 25 and mean refractive indices which was each greater than

1.65 and differ by between 0.05 and 0.15.

An optical objective as claimed

An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front with the second member is concave to the front with the rear author of such component is convex to the front with reduce of such component is convex to the front with reduce of such component is convex to the front.

An optical objective as claimed in claim 2, in which the doublet component constituting the third member has a collective internal contact convex to the front, with mading of superture lying summerically between 0.55, and the materials of the two elements of such internal

component having labe vanues and either by some that different by some that is not been a few and the second of th

An optical objective on claimed in claim 1, in

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which the front surface of the compound component of the second member is duncave to the front . turveture lying numerically between 1.50 the rest surface of such component is convex to the An obtical objective as claimed in claim 5, in which the radi: of curvature of the front and rear surfaces of the simple wenters component of the second member respectively lie numerically between 1.51, and which between 0.65 $f_{\rm m}$  and  $f_{\rm m}$ . An optical objective as claimed in claim, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements, the meterials enotice the duterials of all the elements of the second number having mean refractive indices greater than 1, and being such that the 20 srithmetic mean botseen the Abbe V numbers of the meterials of the divergent elements exceeds that of the convergent element by at lough 25. An optical objective as claimed in claimit. including an achromatic doublet which can be placed at will behind the stationary rear member of the objective 25 and acte when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation. An optical objective as claimed in claim 1, in which the radise of curvature of the front surface of

simple menicus component of the second member lies numerically between 1.5f. and 3fp.

An optical objective as claimed in claim 1, in which the radius of currety to of the rear nurface of the simple meniscus component of the second member lies

numerically between 0.65fg and fg.

An optical objective as claimed in claim 1, in which the compound component of the second member consists of a triplet component having a convergent element between

An optical objective as claimed in claim 15, in

two divergent elements.

which the doublet component constituting the third member cas a collective internal contact convex to the front with radius of curvature lybus numerically between 0.5f, and f. . the materials of the two elements of such component having the V numbers which differ by mure than 25 and mean cellective indices which are each speaker than 1.65 and diver by between 0.05 and 0.15. An optical of jective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature lying numerically between U.SI, and I., the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15. whilst the difference between the Abbe V numbers of such

An optical objective as claimed in claim 17.13 including an achromatic doublet which can be placed at

30 will behind the stationary rear member of the objective

paterials exceeds 25.

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and acts when in its operative position to increase the values of the equivalent Forel length of the objective by a chosen ratio throughout the range of variation, An optical objective of the room type (that as of the type having relatively novable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining negstant position of the image plane), corrected for apherical and chromatic aberrations, come, astigmatism, field curvature and distortion, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, on axially movable divergent second couper behind the first wember baving equivalent focal length fn lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially novable divergent third member behind the second member having equivalent focal length  $f_{\rm C}$  lying numerically between 5 and 10 times the minimum value of such ratio, a statistiary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control causes the gooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between  $1.5f_{\rm R}$  and  $2.5f_{\rm R}$  and the total sxial movement of the third member in the range lies numerically between C.25f., and O.5f., the minimum sxial separation between

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the second and third members occurring when the

than half its maximum value in the sange of variation. the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, the movable divergent third member consisting of a doublet component having its front surface conceve to the front, with redive-ofcurvature lying numerically between 0.5£, and l.Of., and the first member of the objective comprises a meniscus doublet component having a front surface which is concave to the front and has dispersive optional power lying numerically between 0.5/f, and 1.0/f, (where f the controllent formal langth of the first sember) and two simple convergent components behind such meniscus doublet component. An optical objective as claimed in claim, in which the internal contact of the meniscus coublet component of the first member is dispersive and convex to the front, with radius of curvature between 1.5f. and the difference between the mean refractive indices of the materials of the two elements of the doublet Act being greater than 0.15 and in which the arithmetic mean between the Abbe V numbers of the raterials of the three . , convergent elements or the pret member exceeds by at least 20 the Abbe V number of the material of the

divergent front element of the meniscus doublet component

in which the compound component in the divergent movable

An optical objective as claimed in claim #0.

e-wivalent focal length of the objective is greater

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of the first member.

9295 second member includes at least one convergent element and at least one divergent element, and the V numbers differ by more than 35, and doublet component constituting the third member has a collective internal contact convex to the front. withradius of curvature lying numerically between 0.5f. and fo, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each speater than 1.65 and differ by between 0.05 and C. 10 An optical objective as claimed in claim 2. in which the two simple components of the first member together have a combined control of total boost) tetmeen 0.75£; and 1.25£, and have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being bees than his and greater than twice the radius of curvature of the front second of such simple components, white surface of the second of the two simple components being convex to the front, with radius of ourvature between REA and 7EA. An optical objective as claimed in claim 22, 25 in which the radii of curvature of the front and rear surfaces of the simple mediscus component of the second member respectively lie numerically between  $1.5f_{\rm B}$  and 3f and between 0.66fn and fn. An optical objective as claimed in claim 15,65 30 in which the axial thickness of the meniscus doublet

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is greater than the sum of the small thicknesses of the two aimple components of the first member, such same in the being greater than 0.075£, the equivalent focal length fa of the first member lying between 1.2 and 2.4 times the maximum varie of the ratio of the equivalent focal length of the ratio of the equivalent focal length of the ratio of the equivalent focal length of the ratio of the procedure of the objective in the range of variation.

including an achromatic doublet which can be placed at will behind the staticsary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

An optical objective as claimed in claim in including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the enuvelent focal length of the objective by a chosen ratio throughout the range of variation.

27. An optical objective as claimed in claim 25, in which the internal contact of the menicus doublet component of the first member is dispersive and convex to the front with radius of curvature between 1.5% and 3%, the difference between the mean refractive indices of the materials of the two elements of the couplet

being greater than 0.15.

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## DECLARATION, PETITION AND POWER OF ATTORNEY

declare that we are outligeneros, Subjects respectations, and residents of Dadby. County of Leicester, England; and Prestatyn, County of Flintshire, Wales, United Kingdom, respectively; that we have read the foregoing specification and claims, that we verily believe ourselves to be the original, first and joint inventors of the improvement in OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH described and claimed in the foregoing specification; that this application in part discloses and claims subject matter disclosed in our earlier filed pending application Serial No. 309,208 , filed September 16, 1963 , that as to to subject matter of this application which is common to said earlier application we do not know and do not believe that the same was ever known or used before our invention thereof or patented or described in any printed publication in any country before our invention thereof or more than one year prior to said earlier application, or in public use or on sale in the United States more than one year prior to said earlier application; that said common subject matter has not been patented before the date of said earlier application in any country foreign to the United States on an application filed by us or our legal representstives or assigns more than twelve months prior to said application; and that the earliest application for patent on said invention filed by us or our legal representatives

or assigns in any country foreign to the United States was:

Great Britain - No. 35088 filed Sept. 14, 1962

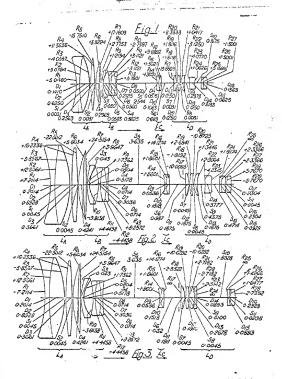
that as to the subject matter of this application which is not common to said earlier application, we do not know and do not believe that the same was ever known or used before our invention thereof or patented or described in any printed publication in any country before our invention thereof or more than one year prior to the date of this application, or in public use or on sale in the United States more than one year prior to the date of this application, and that said subject matter has not been patented in any country foreign to the United States on an application filed by us or our legal representatives or assigns more than twelve months prior to the date of this application; and that no application for patent on said invention has been filed by us or our legal representatives or assigns in any country foreign to the United States.

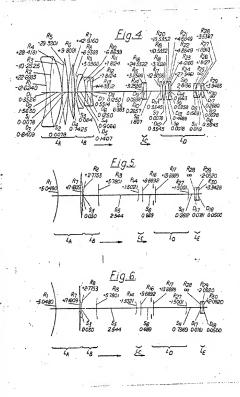
And we declare further that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

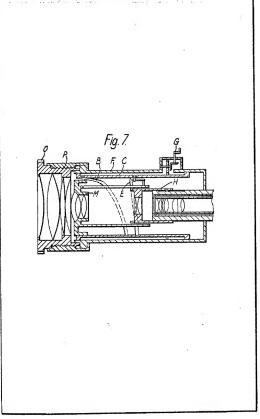
And we hereby appoint HOLOOMEE, WETHERILL & BRISEBOIS, a firm having offices at Suite 307, Crystal Plaza Building No. 1, 2001 Jefferson Davis Highway, Arlington, Virginia 22202, Registration No. 17,348, our attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith.

Wherefore we pray that Letters Patent be granted to us for the invention or discovery described and claimed in the foregoing specification and claims, and we hereby subscribe our names to the foregoing specification and claims, declaration, power of attorney, and this petition,

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## U.S. DEPARTMENT OF COMMERCE Patent Office

Address Only: COMMISSIONER OF PATENTS Washington, O.C. 20231

HOLCOMBE, WETHERILL & BRISEBOIS SUITE 307

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	RY COOK, et. a
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RECEIVED

IN THE UNITED STATES PATENT OFFICE

DEC 9 1971

In re application of

GORDON HENRY COOK et al

Serial No. 152,254

Filed June 11, 1971

riled June 11, 1973

Por: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT POCAL LENGTH December 2, 1971

JR 259

LETTER

Hon. Commissioner of Patents Washington, D.C. 20234

Sir:

Responsive to the enclosed letter, please transfer from the file of the parent application, SN 309,208, filed September 16, 1967, (now abandoned), the two sheets of drawings in that case. These correspond to the two informal prints intially filed with the above-entitled application.

Respectfully submitted,
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550

Joseph F. Brisebois Reg. 15,965



# U.S. DEPARTMENT OF COMMERCE Patent Office

Address Dniy: COMMISSIONER OF PATENTS Washington, D.C., 20201

J. K. Corbin	Group 259	14	
06/11/71	152-254	Paper No	
COOK . GORDON HENR	Y. ET. AL.		
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HOLCOMBE. WETHERING	LL 6		
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SUITE 307. ARLINGTON: VA. [2]		This is a communication from the Exami charge of your application.	ner.
		Commissioner of I	Pater
	•		
This application has been exa	amined.		
Responsive to communication	n filed	. This action is made final,	
A SHORTENED STATUTORY	PERIOD FOR RESPONSE	TO THIS ACTION IS SET TO EXPIRE	
Three MONTH	(S)DAYS FROM	THE DATE OF THIS LETTER.	
	PART I		
The to	illowing attachments(s) are par	t of this action:	
a. Notice of References Cited, Fo	orm PO-892, b Notice o	of Informal Patent Drawing, PO-948.	
<ul> <li>C. Notice of Informal Patent Ap. Form PO-152,</li> </ul>	plication, d.		
	PART II		
1. # Claims 1-27	Summary of Action	are presented for examination.	
2. CIBIMS		are allowed.	
3. Claims		would be allowable if smended as indicated.	
4. D Claims 1-27		are rejected.	
5. Claims		are objected to.	
6. Claims		re subject to restriction or election requirement.	
7, Claims		are withdrawn from consideration.	
		e except for formal matters, prosecution as to ti Quayle, 1935 C.D. 11; 453 OG, 213,	he
		e may result in agreements whereby the application of the representative within about 2 week.	
10. Receipt is acknowledged of pa	pers under 35 USC 119, which pa	apers have been placed of record in the file.	
11. Applicant's claim for priority be is acknowledged. It is noted, he		ononon received.	_
12. Cther		<u> </u>	
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POL 326 (10/70)

A separate letter to the Draftsman for correcting the curvature of  $\mathbf{R}_7$  to show that it is slightly convex to the front, as submitted in the parent case, should be submitted in the present case.

The Yamaji, Harris et al, and Klemt et al patents are cited to show the state of the art.

Claime 1-27 are rejected under 35 U.S.C. 112, first peragraph, as based on a disclosure which fails to establish the validity of the numerical ranges for certain of the lens parameters. The numerical embodiments in the specification clearly do not support the validity of the ranges. Further the explanation in the specification, pages 16-20, fails to explain most of the ranges æt forth in the dependent claims. The explanation on pages 16-20, however, does appear to establish the truthfulness of the ranges in parent claim 1 except for the one in the last two lines. The reasoning set forth in In re Cook and Merigold 169 USPQ 298, and especially as set forth on page 303 is applicable to the last range in claim 1 and those in the dependent claims.

Allowable subject matter is consider present in the disclosure.

J. K. Corbin:vgr 703/557/3107 5-16-72 JOHN K. CORBIN
EXAMINER
GROUP ART HINT 259

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## U.S. DEPARTMENT OF COMMERCE Patent Office

Address Only: COMMISSIONER OF PATENTS Washington, D.O. 20231x

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152,254 OPFICAL OB	6-11-71
SERIAL NUMBER	FILING DATE
	RY COOK,et.al
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DECEIVED

IN THE UNITED STATES PATENT OFFICE

In re application of

November 6, 1972

GORDON HENRY COOK et al

Serial No. 152,254

Gr.Art Unit 259
N Edge

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Exr. J. K. Corbin

## AMENDMENT

Hon. Commissioner of Patents Washington, D.C. 20231

Sir:

Responsive to Official Action mailed August 4, 1972. please amend the above-entitled application as follows:

> Claim 1, next to last line, cancel "with radius" and substitute a period;

> > cancel the last line.

than 25".

Claim 2, line 5, cancel "whose" and substitute -- of differing --: cancel "differ by more

Cancel Claim 3.

Claim 4. line 1. cancel "3" and substitute --2--;

line 3, cancel "with radius of" and substitute

--and--:

cancel line 4:

at the end of line 5 insert a period: cancel lines 5 and 7.

Claim 5, line 4, cancel "the materials of the elements of" and substitute a period:

cancel lines 5-11 inclusive.

Claim 6, at the end of line 3 insert a period; cancel lines 4-8 inclusive.

Claim 7, line 3, cancel "with radius of" and substitute --and--;

cancel line 4:

at the end of line 5 insert a period; cancel lines 6 and 7.

Claim 8, at the end of line 3 insert a comma;

cancel line 4;

line 5, cancel "and fo,";

line 6. after "having" insert --differing --; cancel "which differ by more than"'

line 7, cancel "25"; after "and" insert

--differing --: cancel "which are each greater" and substitute a period;

cancel the last line.

Claim 9, line 3, cancel "with radius of" and substitute

--and--:

cancel line 4:

at the end of line 5 insert -- front .--:

cancel lines6 and 7.

Cancel Claim 10.

Claim 11, line 4, cancel "the materials of the elements

cancel line 5:

line 6, cancel "by less than 0.15 from one another":

Claim 11, line 8, cancel "1.65" and substitute --1.69--; last line, cancel "by at least 25".

Cancel Claims 13 and 14.

Rewrite Claims 16 and 17 as follows:

-UE/2 (Amended) An optical objective as claimed in Claim 15. in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature [lying numerically between  $0.5f_{
m c}$  and  $f_{
m c}$ ] substantially equal to 0.72 $\underline{f}_{\mathbb{C}}$ , the materials of the two elements of such component having Abbe V numbers which differ by [more than 25] about 30 and mean refractive indices which are each greater than [1.65] 1.69 and differ by [between 0.05 and 0.15]

ALA! (Amended) An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature [lying numerically between  $0.5\underline{r}_{C}$  and  $\underline{r}_{C}$ ] substantially equal to  $0.72\underline{r}_{C}$ , the difference between the mean refractive indices of the materials of the two elements of such component [lying between 0.05 and 0.15] being about 0.09, [whilst] while the difference between the Abbe V numbers of such materials [exceeds 25] is about 30.4

> Claim 19, line 35, cancel "with radius of" and substitute a comma;

> > cancel line 36:

line 39, cancel "has dispersive optical

cancel lines 40 and 41.

-3-

Claim 20, cancel line 4, and substitute --to the front.-; cancel lines 5-12 inclusive.

Claim 21, line 4, cancel "made of materials" and substitute --, and the--;

cancel line 5;

line 7, cancel "with" and substitute a period; cancel lines 8-12 inclusive.

Glaim 22, cancel line 3 and substitute --together--; line 4, cancel "between 0.75 $\underline{r}_A$  and 1.25 $\underline{r}_A$ ,

line 7, cancel "less than hr and";
line 9, cancel "which latter radius" and
substitute --the rear--;

cancel line 10;

line 12, cancel "with radius of curvature"
and substitute a period;
cancel the last line.

Cancel Claim 23.

Claim 24, line 3, cancel "less than 0.25f<sub>A</sub> and";
line 5, cancel ", such sum in" and substitute
a period;

cancel lines 6-10 inclusive.

Rewrite Claim 27 as follows:

(Amended) An optical objective as claimed in claim 24, in which the internal contact of the meniacus doublet component of the first member is dispersive and convex to the front with radius of curvature [between 1.5f<sub>A</sub> and 3f<sub>A</sub>] substantially equal to 2.04f<sub>A</sub>, the difference between the mean refractive indices of the materials of the two elements of the doublet being [greater than 0.15] substantially 0.27.

az

### REMARKS

The criticized range in the last two lines of Claim 1 has been eliminated, since the approximate curvature of the front surface of the third member may be deduced by a skilled lens designer to lie within this range, once he has been given the basic information contained earlier in the claim.

The dependent claims have likewise been amended to eliminate unsubstantiated ranges.

The required letter to the Official Draftsman is attached hereto.

Since none of the references were applied to the claims, the application is now presumed to be in condition for allowance.

Respectfully submitted,

GORDON HENRY COOK et al

521-1550 JFB:gw By Soft White Joseph F. Brisebois Reg. 15,965 HOLCOMBE, WETHERILL & BRISEBOIS



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GROUP 250

### IN THE UNITED STATES PATENT OFFICE

In re application of

November 6, 1972

GORDON HENRY COOK et al

Serial No. 152,254

Gr.Art Unit 259

Filed June 11, 1971

Exr. J. K. Corbin

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

LETTER TO OFFICIAL DRAFTSMAN

Hon. Commissioner of Patents Washington, D.C. 20231

Sir:

Please correct the surface  $\pi_7$  in each of Figures 1-6 to show it as slightly convex to the front, as indicated in red on the attached prints, and charge the cost of this work to our Miscellaneous Account No. 08-2720, Order No. 53.

Respectfully submitted, GORDON HEMRY COOK et al

521-1550 JFB:gw By /// Brisebois Reg.15,965 MOLCOMBE, WETHERILL & BRISEBOIS

CORRECTED

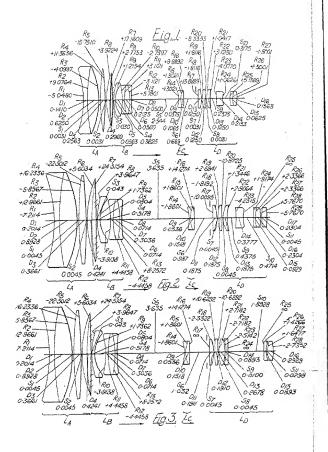
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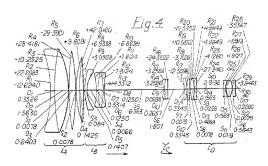
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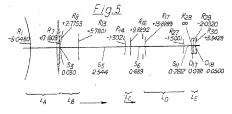
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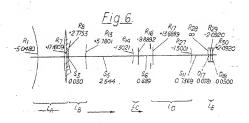
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## U.S. DEPARTMENT OF COMMERCE

Address Only: COMMISSIONER OF PATENTS

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Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents

# CHANGES AND/OR ADDITIONS TO THE APPLICATION RECORD MADE BY THE EXAMINER UPON ALLOWANCE

This application is in condition for allowance and the following changes have been made therein by the Examinor. Should the changes be unecceptable to applicant, an appropriate amendment may be proposed after the Notice of Allossance has been received, as provided under Rule 312. To ensure consideration of such an amendment, it must be submitted on or before remittance of the Base Issue Fess.

PROSECUTION ON THE MERITS IS CLOSED. A NOTICE OF ALLOWANCE WILL BE MAILED IN

[1] Note attached Notice of References Cited, PO-892, which is part of this communication. The listed references are considered to be pertinent to the claimed invention, but the claims are deemed patentially thereover.

In line 8 of page 3 ---, now abandoned---been inserted after "1963".

J. K. Corbin: sas

703/557/3107

11-17-72

John X. Carbin

JOHN K. CORBIN EXAMINER GROUP ART UNIT 259

PLEASE FURNISH YOUR 2IP CODE IN ALL CORRESPONDENCE

All communications regarding the application should give the smill sumber, date at filing, and name of the positions.



### U.S. DEPARTMENT OF COMMERCE Patent Office

Address Only: COMMISSIONER OF PATENTS Washington, D.C. 2023 I

## NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE

The application identified below has been examined and found allowable for issuance of Letters Patent.

	PRING DATE	SERIAL NO.		NO OF CLAIMS ALLOWED	EXAMINE AND GROUP ART UNIT
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The Base Issue Fee will not be accepted from anyone other than the applicant, his assignee, attorney, or a party

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the assignee's address must be given to ensure its inclusion in the printed patent.

In connection with the address of the inventor(s), attention is directed to Form POL-231 enclosed.

A Notice of Balance of Issue Re Due with a midel together with the pathete's copy of the patent if an additional fee is due. Payment must be made within titue months from the dote shown on soid Notice since FAILURE TO PAY THIS BALLENE PUTTENT THE TITUE SPECIFIED WITH SPECIFIED IN 18-55 OF THE PATENT

#### IMPORTANT

ATTENTION IS DIRECTED TO RULE 334
REVISED NOVEMBER 4, 1969.

THE PATENT WILL ISSUE TO APPLICANT UNLESS AN ASSIGNEE IS SHOWN IN ITEM 2 ON FORM POL-85b, ATTACHED

PATENT OFFICE COPY

Holcombe, Wetherill, et al 2001 Jefferon Davis Hwy.,

Arlington, Va. 22202

Suite 307

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### IN THE UNITED STATES PATENT OFFICE

In re application of GORDON HENRY COOK et al

Serial No. 152,254

Filed June 11, 1971

For: OFTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

March 9, 1973

Alld. Jan.10,1973

Final Fee Pd. Mar.9,1973

Gr. Art Unit 259

Exmr. Corbin

## CLAIM OF PRIORITY

Honorable Commissioner of Patents Washington, D.C. 20231

Sir:

Applicants hereby claim the priority of their corresponding British application No. 35088 filed in Great Britain,
September 14, 1962 by applicants' assignee RANK PRECISION
INDUSTRIES LIMITED trading as THE RANK ORGANISATION RANK TAYLOR
HORSON DIVISION as is permitted by British law, applicants being
the true and first inventors.

A certified copy of said British application is attached.

Please note that this application is a continuationin-part of application Serial No. 309,208, filed September 16, 1963.

Respectfully submitted,

GORDON HENRY COOK et al

Joseph F. Brisebois Reg.No. 15,965 HOLCOMBE, WETHERILL & BRISEBOIS

521-1550 dkf



SN 152,254 1955 GR 259

THE PATENT OFFICE,
25 SOUTHAMPTON BUILDINGS,
LONDON.

I, the undersigned, being an officer duly authorised in accordance with Section 62(3) of the Patents and Designs Act, 1907, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of documents as originally filed in connection with the Patent application identified therein.



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## Patents Form No. 1



Nam 35088

THIS SPACE FOR OFFICE USE ONLY

Care VII.



## PATENTS ACT, 1949

APPLICATION FOR PATENT

(To be accompanied by two copies of Patents Form No. 2 or of Patent Form No. 3)

Note: This is a comprehensive form and parts inappuropriate to a particular application should be cancelled. In the case of an application by the inventor, only parts 1, 4 and 6 of this form are appropriate, together with part 3 if a Patent of Addition is applied for.

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Leiceater, and Pater (mold MKNIGHD, British Subject, of "Ribbloodnio", 43, Lodgoridd Drive, Thurney, in the County of Meiceater,

to be the true and first inventor s of the invention.

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#### NOTICE TO INVENTORS

Attention of applicants is drawn to the desirability of avoiding publication of inventions relating to any article, material or device intended or adopted for use in war (Official Secrets Acts 1911 and 1920).

In such case, after an application for a patent has been filled at the Patent Office, the Compatibility of the Compatibility considers between publications or communication of the invention Consult by architecture of restricted under Seation 18 of the Act and will inform the applicant if such prohibition is increasery. Applicant are rememded that, indust the provision of this Seation, applications may not be filled abroad without written permit or unless an application has been filed and less that six vecles provincies; in the United Wilson 19 of the Compatibility of th

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PATUITS ACT 1949.

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PROVISIONAL SPECIFICATION.

"INTROVENIESTS IN OR RELATING TO GITIOAL GESTOTIVES OF VARIABLE EQUIVALENT FOCAL LESGIN".

Ve, RANK PRECISION INPUSTRIES LIMITED trading on THE RANK ORGANISATION RANK TAYLOR HOBSON DIVISION, A British Company, of 104, Stoughton Street, Leicester, do hereby declare this invention to be described in the following statement:- This invention relates to an optical objective of the "zoom" type, that is of the type heving relatively nevable members whereby under the centrol of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane, whereby the size of the image can be varied. Accommodation for change of object position is usually schieved by imparting an additional movement to the front member of the objective.

Many difficulties arise in the design of such objectives. and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to sohieve this usually involve the use of relatively complicated movable members in the objective in order to make it possible in such movable members tostabilise the aberrations throughout the range of variation, such stabilised aberrations then being compensated in a stationary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents sovere mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the goom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demonded departures from linearity

of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unsunageable proportions or have introduced too severs optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the scening movements for varying the equivalent focal longth, so that this member is concerned only with focuseing movements and is relieved of the complication of superisposing focuseing movements on scening movements. Buch an arrangement is utilised in the present invention, wherein the primary object is to provide an improved arrangement of the newable system of the objective, which can be employed with various different arrangements of the front member and will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

The optical objective of the soon type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative sevements, the second and third are divergent and wovable, and the fourth is convergent and stationary, the position of minimum members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilet the equivalent focal lengths  $\underline{f}_{B}$  and  $\underline{f}_{C}$  respectively of the movable second and third members lie respectively between 4 and 3

times the minimum value of the ratio of the equivalent focal length of the objective to the g/mamber of the objective in the range of variation and between 5 and 10 times suon minimum ratio, the divergent movable second member consisting of a divergent minimum component with its surfaces convex to the front followed by a divergent compound component and performing during the range of variation a total axial movement lying between  $1.5f_{\rm B}$  and  $2.5f_{\rm B}$ , whilst the divergent sowable third member consists of a doublet component having a front surface concave to the front with radius of curvature between  $0.5f_{\rm C}$  and  $1.0f_{\rm C}$  and performs during the range of variation a total axial movement lying between  $0.25f_{\rm C}$  and  $0.5f_{\rm C}$ 

It is to be understood that the terms "front" and "rear", as used herein, relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

It should also be made clear that the tern "internal "contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the arithmetic mean between the radii of curvature of the individual contacting surfaces, whilet the optical power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall

dimensions of the objective as small as possible and achieving the best compresses between the dissisters and the relative apertures of the individual members of the objective, and also permit the front noish points of the objective, and also permit the front noish points of the occord and third members to be located as for forward as possible, thus unking it possible, not only to accordant the desired mexicants of the members without rick of fouling between the neabers and with minimum increase in the overall length of the objective, but also to achieve a good compression between the disasters and relative apprehence of the individual members, and at the same time to assist towards the desired stabilization of the aberrations, especially of spherical aberration and costs, throughout a widely extended range of variation of the equivalent focal length of the objective.

The compound component in the divergent movable second member preferably includes of least one convengent elegent and at least one divergent element under of materials whose Abbé V numbers differ from one another by more than 15, thus permitting such second member to be individually corrected for chromatic abstraction.

For assisting towards stabilisation of astignation and distortion, the radius of curvature of the front surface of the single members component of the second seaber prescribly lies between  $1.5L_{\rm B}$  and  $3L_{\rm B}$ , and further assistance towards stabilisation of astignation can be obtained by arranging for the radius of curvature of the rear surface of such component to lie between  $0.66L_{\rm B}$  and  $1.0L_{\rm B}$ .

The frost surface of the compound component of the second member is preferably concave to the frost with radius of curvature between 1.5 $\underline{x}_{n}$  and  $\underline{x}_{n}$ , the rear surface of such component being convex to the frost with radius of curvature

between  $\mathfrak{F}_{n}$  and  $\mathfrak{G}_{n}$ , thus assisting towards stabilization of spherical aberration and come.

whilst such compound component may consist of a doublet component, it will assually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials for the various elements, facilitates correction of chromatic aberration and the desired stabilisation of the other aberrations without exceeding curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound commonent in much member do not differ from one shother by more than 0.15. The arithmetic mean between the Abbé V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet commonent constituting the divergent moveble third melber preferably has a collective internal contact convex to the front with radius of convexture between 0.5£0 and £0, the difference between the mean refractive indices of the materials of the two elements of much component lying between 0.05 and 0.15, whilst the difference between the Abbé V numbers of such naterials exceeds 25.

These features contribute towards the desired

6.

stabilisation of opherical abstration and come and also facilitate individual correction of the third member for chromatic abstration.

As in the case of the second member, it is preserable to employ materials for the elements of the third sember having mean refractive indices greater than 1.65, in order to avoid exceesive surface curvatures and thus facilitate the attainment of a wide relative aperture for the member.

A moveble system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially adventageous for such member to have one or more of the following characteristics:-

- A) The first member is preferably convergent andway comprise a front meniscue doublet component with its front and rear surfaces concave to the front surface of the doublet convergent echaponents, the front surface of the doublet convenent having dispersive optical power lying numerically between  $0.5/\underline{f_k}$  and  $1.6/\underline{f_k}$ , where  $\underline{f_k}$  is the equivalent focal length of the first member. These features permit the rear nodal point of the first member to be far to the rear and preferably behind the rear surface of the number, for cooperation with the forwardly located front nodal point of the second member.
- B) The internal contact of the meniscue doublet component of the first member may be dispersive and convex to the front with radius of curvature between  $1.5f_{\rm A}$  and  $3f_{\rm A}$ , the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater

- than 0.15. These features contribute towards emphilication of spherical aberration and satisfaction over the desired focussing range to sait different object distances.
- c) The two simple components of the first member may together have a combined equivalent rocal length between 0.75f<sub>A</sub> and 1.25f<sub>A</sub>, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than 4f<sub>A</sub> and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than 0.75f<sub>A</sub>. These features assist towards stabilizing the abstration, especially spherical abstration and satignatise, not only throughout the range of focussing adjustments, but also throughout the range of variation of equivalent focal length.
- N) The rear surface of the rear component of the first member may be convex to the front with radius of curvature between 2f<sub>A</sub> and 7f<sub>A</sub>. This feature contributes towards stabilisation of primary antigmatism throughout the runge of focusaing adjustments, and also of primary and higher order artigmatism throughout the runge of variation of equivalent focal length.
- b) The axial thickness of the meniacus doublet component of the first member may be less than 0.25 \(\int\_A\) and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than 0.075 \(\int\_A\). These features contribute towards the desired rearward location of the rear nodal point of the first member.
  - k) The arithmetic mean between the Abbé V numbers of

the materials of the three convergent elements of the first member may exceed by at least 20 the libe V number of the meterial of the divergent front element of the moniscus doublest component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G) The equivalent focal length  $f_A$  of the first member may lie between 12 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f/number of the objective. This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

Various combinations of the foregoing features may be incorporated in the arrangement of the first member, and it is especially advantageous to arrange such member in accordance with the invention forming the subject of the present applicants' British Fatent Application No. 35053 of 1962. Filed concurrently herewith. The objective in accordance with the invention of such concurrent patent application has four members of which the first for a given object distance remains stationary during the sooming relative movements, the second and third members are movable, and the fourth is stationery. at least one of the movable second and third members being divergent, whilst the first member is convergent and comprises a front menisous doublet component followed by two simple convergent components, such doublet commonent having a front surface concave to the front with dispersive optical power lying numerically between 0.5/f, and 1.0/f, and an internal contact which is dispersive and convex to the front with radius of curvature between 1.5f. and 5f., the difference

between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15, whilst the two simple components of the first member together have a combined equivalent focal length between 0.75 $f_A$  and 1.25 $f_A$  and have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being less than  $4f_A$  and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature is in turn greater than 0.75 $f_A$ .

In all the arrangements according to the present invention, it is preferable for the iris disphragu of the objective to be stationary and to be located behind the movable third member of the objective.

Numerical data for eone convenient printical examples of more objective according to the present invention are given in the following tables, in which  $R_1,\,R_2,\ldots$  designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and the negative sign that it is concave therets,  $D_1,\,D_2,\ldots$  designate the axial thicknesses of the individual elements of the objective, and  $S_1,\, U_2,\ldots$  designate the axial air separations between the components of the objective. The tables also give the mean refractive indices  $\underline{n}_{\underline{0}}$  for the  $\underline{0}$ -line of the spectrum and  $\underline{v}$  the Abbé  $\underline{v}$  numbers of the materials from which the various clements of the objective are made, and in addition the clear disasters of the various curfaces of the objective.

The second scotten of each table gives the values of the three variable usual air deparations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value  $F_0$  to its maximum value  $F_0$  are also given, together with the corresponding values of log F.

Some of the tables also have a third section giving the equation defining an axial section through an aspheric surface provided in the stationary recrustation of the objective, the radius of curvature given formula curface in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensiona in each table are given in terms of  $\mathbb{P}_{_{\mathbf{O}}}$ 

Brando 1.

Radius	Thickness or Air Separation	Refractive Index nd	Abbé V Kumbor	Clear Classeter.
R <sub>1</sub> - 5.0480	D <sub>1</sub> 0.1410	1.7847	26.10	R <sub>1.</sub> 3.4435
H <sub>2</sub> + 9.0764	D <sub>2</sub> 0.6250	1.51507	56.35	R <sub>2</sub> 3.4750
R <sub>3</sub> - 4.0997	s <sub>1</sub> 0.0031			R <sub>3</sub> 3.4670
R <sub>4</sub> + 11.3636 R <sub>-</sub> - 15.7510	D <sub>5</sub> 0.8563	1.717	47.90	H <sub>E</sub> 3.3715 H <sub>C</sub> 3.3610
R <sub>5</sub> - 15.7510 R <sub>6</sub> + 3.9224	s <sub>2</sub> 0.0031			2
R <sub>7</sub> + 17.1609	D <sub>4</sub> 0.2969	1.717	47.90	R <sub>6</sub> 3.1035 R <sub>7</sub> 3.0707
R <sub>8</sub> + 2.7753	S <sub>5</sub> variable			₩ <sub>B</sub> 1.7000
R <sub>9</sub> ·+ 1.2154	D <sub>5</sub> 0.0563	1,69734	56.10	Rg 1.4912
m <sub>10</sub> - 2.7397	s <sub>4</sub> 0.3625			R <sub>10</sub> 1.4712
R <sub>11</sub> + 3.1121	D <sub>6</sub> 0.0500	1.69734	56.39	R <sub>11</sub> 1.4092
R <sub>12</sub> - 3.1121	Dy 0.2125	1.7847	26.30	H <sub>12</sub> 1.3947
B <sub>13</sub> + 5.7301	D <sub>8</sub> 0.0500	1.69734	56.19	R <sub>13</sub> 1.3412
R <sub>14</sub> - 1.3021	S <sub>5</sub> variable			R <sub>14</sub> 0.7807
R. + 1.3021	D <sub>9</sub> 0.0375	2.69734	56.19	R <sub>15</sub> 0.8205
R <sub>16</sub> + 9.8892	D <sub>10</sub> 0.1063 S. verteble	1.7847	26.30	K <sub>1.6</sub> 0.8300
R <sub>17</sub> + 13.8889	e -	1.524	58,57	R <sub>17</sub> 0.8865
R <sub>18</sub> - 1.8116	TT	** • 2 m.	20101	R <sub>18</sub> 0.9017
R <sub>19</sub> + 1.8116	B <sub>7</sub> 0.0031 D <sub>12</sub> 0.1250	1.524	58,87	R <sub>19</sub> 0.9157
H <sub>20</sub> - 8,3333	8 <sub>8</sub> 0.0031		,,,,,	g <sup>50</sup> 0.3105
	D <sub>13</sub> 0.1250	1.524	58.87	B <sub>21</sub> 0.8858
				R <sub>22</sub> 0.0602
	S <sub>9</sub> 0.2373 (aspheric) D <sub>14</sub> 0.2133	1.7285	28.66	R <sub>23</sub> 0.7560
24	810 0.3175			R <sub>24</sub> 0.6907
R <sub>25</sub> + 5.1589	D <sub>15</sub> 0.0625	1.7283	28.66	R <sub>25</sub> 0.7197
	D <sub>16</sub> 0.1563	1.61492	56.22	R <sub>26</sub> 0.7200 R <sub>27</sub> 0.7225

S.,	s <sub>5</sub>	86	P	log P	,
0.03023	2,54423	0.68858	1.00000	0.00	
1.11409	1.40738	0.74157	1.77827	. 0.25	
1:93430	0.60533	.0.72521	3.16227	0.50	
2.55076	0.1610%	0.55325	5.02339	0.75	٠,
2.96233	0.16657	0.13414	10,00000	1.00	

Equation for aegheric surface 
$$R_{23}$$
  
 $\underline{x} = -4.077 + \sqrt{16.62193 - x^2} - 0.02455203 x^4 + 0.08459172 x^5$   
 $= 0.2440590 x^8 - 0.07442450 x^{10}$ 

Example 11

Radius	Thickness or Air Deparation	Beiractive Index ng	Abbó V Bumbor	Clear Dimmeter
n <sub>1</sub> - 7.211/4	D. 0.2014	1,7847	26,10	R <sub>1</sub> 4.9192
R <sub>2</sub> + 12,9661	1.	1.7647	56,35	R <sub>2</sub> 4.9642
13 - 3.8567	6	T+DTDA1	50,√55 CC.*QC	R 4.9814
R <sub>4</sub> + 16.2536	S <sub>1</sub> 0.0045	2 22 25 25 25	*** ***	R4 4.0164
R <sub>5</sub> - 22.5012	D <sub>3</sub> 0.3661	1.7170	47.90	R <sub>5</sub> 4.8014
K <sub>6</sub> + 5.6034	S <sub>2</sub> 0.0045	- 42-911		R <sub>6</sub> 4.4335
Ny + 24.5154	D <sub>4</sub> 0.4241	1.7170	47.90	R <sub>7</sub> 4.3867
n <sub>8</sub> + -3.9647	3, variable			R <sub>8</sub> 2.4286
Ng + 1.7362	D <sub>5</sub> 0.0804	1.69734	56.19	R <sub>g</sub> 2.1161
N <sub>10</sub> - 3.9153	S <sub>4</sub> 0.5178			R <sub>10</sub> 2.1618
N <sub>11</sub> + 4.4459	D <sub>6</sub> 0.0714	1.69734	56.19	R <sub>13</sub> 2.0132
R <sub>12</sub> - 4.4458	D <sub>7</sub> 0.3036	1.7847	26.10	R <sub>12</sub> 1.9925
H <sub>13</sub> + 8,2572	D <sub>8</sub> 0.0714	1.69734	56.19	R <sub>13</sub> 1.9161
R <sub>14</sub> - 1.8601	S <sub>5</sub> variable			R <sub>14</sub> 1.1153
%15 + 1.8601	D <sub>9</sub> 0.0536	1.6973/	56.19	R <sub>15</sub> 1.1721
£ <sub>16</sub> + 14.1274	D <sub>10</sub> 0,1518	1.7847	26.IO	15 1.1857
E <sub>17</sub> = 10.0095	S <sub>6</sub> variable			
	D <sub>11</sub> 0.1975	1.5158	64.20	R <sub>17</sub> 1.2592
70	87 0.0045			R <sub>18</sub> 1.2361
73	D <sub>12</sub> 0.1875	1.5168	64,20	R <sub>19</sub> 1.3116
h <sub>20</sub> - 10.8725	s <sub>8</sub> 0.0045			R <sub>20</sub> 1.3033
H <sub>21</sub> + 1,3446	D <sub>13</sub> 0.1875	1.5168	64.20	R <sub>21</sub> 1.2672
R <sub>22</sub> + 2.9064	w,			R <sub>22</sub> 1.2220
R <sub>23</sub> - 4.2315	S <sub>9</sub> (Aspheric) D <sub>14</sub> 0.3777	1.7283	28.66	R <sub>23</sub> 1.0500
R <sub>24</sub> + 1.9174	S <sub>10</sub> 0.4714			H <sub>24</sub> 0.9686
R <sub>25</sub> ∞	D <sub>15</sub> 0.0929	1.7283	28.66	R <sub>25</sub> 1.0019
R <sub>26</sub> + · 2.3366	D <sub>16</sub> 0.2304	1.61342	59.27	A <sub>26</sub> 1.0086
R <sub>27</sub> - 2.3366	20	A+V#2	57.4.	R <sub>27</sub> 1.0186
R <sub>28</sub> + 5.7670	1.1	1.61342	59.27	R <sub>28</sub> 1.0068
R <sub>29</sub> - 5.7670	D <sub>17</sub> 0.2304	1.0174	33.41	h <sub>29</sub> 0.9770

83	s	<sup>5</sup> 6	¥	log P
0.04318	3.63462	0.93730	1.00000	0.00
1.59156	2.01054	1.06300	1.77627	0.25
2.76329	0.86219	1.03962	3.16227	0.50
3.64395	0.23005	0.79109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

Equation for aspheric surface Box

$$= \underbrace{\times} = -4.2315 + \sqrt{17.50539 - \underline{\chi}^2} - 0.01665305 \underbrace{\chi}^4 + 0.02010433 \underbrace{\chi}^6$$
$$- 0.00146346 \underbrace{\chi}^6 - 6.03553300 \underbrace{\chi}^{10}$$

Sweeple III.

Rndi	ue		Thickness or		Refractive	Abbó V		Olosr	
				Separation	Index n	Humber	Din	Disposer	
R <sub>1</sub>	-	7.2114	Dj	0.2014	1.7047	26.10	113.	4.9192	
12	+	12.9661	D <sub>2</sub>	0.8928	1.51507	56.35	$a_2$	4.9842	
R <sub>3</sub>	-	5.8567	S <sub>1</sub>	0.0045			R	4.0014	
R <sub>4</sub>	+	15.2336	D <sub>3</sub>	0.3661	1.7170	47.90	$R_4$	4.0164	
ns	-	22.5010	S2	0.0045			115	4.8014	
$n_6$	+	5.6034	DA	0.4241	1.7170	47.90	$R_6$	4.4355	
R <sub>7</sub>	÷	24.5154	53	variable	÷		R7	4.3867	
$R_8$	4.	3.9647	n <sub>s</sub>	0.0804	1.60734	56.19	Rg	2.4235	
Rg	+	1.7362	S <sub>4</sub>	0.5178			$R_9$	2.1161	
R <sub>10</sub>		3.9138	D <sub>6</sub>	0.0714	1.69734	56.19	R <sub>10</sub>	2.1018	
R <sub>11</sub>	+	4.4453	D <sub>7</sub>	0.3036	1.7847	26.20	R <sub>11</sub>		
R <sub>12</sub>	~	4.4458	DB	0.0714	1.69734	56.19		1.9025	
R13	+	8,2572	85	veriable		•	R <sub>23</sub>	1.9161	
R <sub>14</sub>	-	1.8601	Dg	0.0536	3.69734	56.19	$n_{14}$	1.1195	
R <sub>15</sub>	+	1.8601	D <sub>10</sub>	0.1518	1.7847	26.10	R <sub>15</sub>	1.1721	
R <sub>16</sub>	+	14.1274	\$6	variable	•		$R_{16}$	1.1857	
R <sub>17</sub>		3	D <sub>11</sub>	0.1911	1.524	58.07	P <sub>17</sub>	1.2830	
H <sub>18</sub>	-	2,3322	87	0.0045			R18	1.3098	
R <sub>19</sub>	+	10.6292	D <sub>12</sub>	0.1910	1.524	58.87	R <sub>19</sub>	1.3233	
R <sub>20</sub>	*	10.6292	38	0.0045			R <sub>20</sub>	1.5233	
Ř <sub>21</sub>	4	2.7612	D <sub>13</sub>	0.2678	1.61342	59.27	R <sub>21</sub>	1.3273	
R <sub>22</sub>	-	2.7012	s <sub>9</sub>	0.0100			R <sub>22</sub>	1.7060	
R <sub>23</sub>	~	2.5142	D <sub>14</sub>	0.0893	1.72830	28.66	R23	3. 3049	
R <sub>24</sub>		60	s <sub>10</sub>	1.8928			R <sub>24</sub>	1.2033	
R <sub>25</sub>		90	D <sub>15</sub>	0.0893	1.72830	28.66	R <sub>25</sub>	0.9600	
R <sub>25</sub>	+	1.4256	S <sub>11</sub>	0.0298			R <sub>26</sub>	0.9600	
R <sub>27</sub>	+	1.6477	D <sub>16</sub>	0.2929	1.69734	56.19	n <sub>27</sub>	0.9600	
R28		2.7352	4.5				R <sub>28</sub>	0.9603	

<b>s</b> <sub>5</sub>	36	P	log T
2.63462	1.0319	1.00000	0.00
2.01054	1.1076	1.77827	0.25
0.86219	1,05622	3.16227	0.50
0.23005	0.83569	5.62339	0.75
0.23796	0.23984	10.00000	1.00
	2.63462 2.01054 0.86219 0.23005	2.63462 1.0319 2.01054 1.1076 0.96219 1.08422 0.23005 0.83569	5,63662 1.0319 1.00000 2,01054 1.1076 1.77827 0.96219 1.09622 3.16227 0.23005 0.83069 5.62339

In all these examples, the various value  $\mathbb{F}_{\underline{L}}$  of the equivalent focal length  $\mathbb{F}$  of the objective is ten times the minimum value  $\mathbb{F}_{\underline{L}}$  thereof. Example I is corrected for a relative aperture f/4.0, whilst Examples II and III are each corrected for a relative aperture f/2.8. Examples II and III differ from one another solely in the stationary rear number, the front three members being identical in the two examples. Such froat three members are in fact similar to the front three members of Example I, the dimensions being scaled up from those of Example I, the fraction of the framework, that is in the ratio 4.0/2.3. The rear members in Examples II and III are, however, not scaled-up vermions of the rear member of Example I. All times examples cover a cent-engular field of view varying from 27 degrees at  $\mathbb{F}_p$ , to 3 degrees at  $\mathbb{F}_p$ .

The iris displaced in all three examples is stationary and is located between the morable third member and the stationary fourth member. In Example 1 the displacement of 0.0625  $F_0$  in front of the surface  $R_{17}$  and has dismeter 0.6568  $F_0$ , whilst in Example II the displacement is 0.0929  $F_0$  in front of the surface  $R_{17}$  and has dismeter 1.2240  $F_0$ , and in Example III it is 0.1375  $F_0$  in front of the surface  $R_{17}$  and has dismeter 1.224  $F_0$ .

The back focal distance from the rear surface of the objective to the image plane is 2.8301  $F_{\rm o}$  in Example I, 2.6761  $F_{\rm o}$  in Example II and 2.3027  $F_{\rm o}$  in example III.

All three examples incorporate the invention of the concurrent British Fatent Application above mentioned.

The equivalent focal longth  $f_A$  of the stationary first member is + 4.4551  $F_0$  in Example I and + 6.3644  $F_0$  in Examples II and III; the equivalent focal length  $f_B$  of the movable cocond member is - 1.4753  $F_0$  in Example I and - 2.1004  $F_0$  in Examples II and III; the equivalent focal length  $f_B$  of the movable third member is - 1.0176  $F_0$  in Example I and - 2.5966  $F_0$  in Examples II and III; and the equivalent focal length  $f_B$  of the stationary fourth member is + 1.4755  $F_0$  in Example II, + 2.1266  $F_0$  in Example III; the positive and negative signs respectively indicating convergence and divergence.

In all three examples, the convergent stationary front member consists of a menisum doublet component followed by two convergent simple components. The front surface  $\mathbf{R}_1$  of the doublet component is concave to the front and has disposed vertical power numerically equal to 0.1554/ $F_0$  or  $0.6924/f_A$  in Example I,  $0.1009/F_0$  or  $0.6924/f_A$  in Example II and III. The internal contact  $\mathbf{R}_2$  of the doublet component is dispersive and convex to the front and has radius of curvature equal to 2.0373  $f_A$  in all three examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is .27 in all three examples.

The cumbined equivalent focal length of the two simple components of the first member is 4.6013  $F_0$  or 0.8961  $f_A$  in Example 1, 5.7162  $F_0$  or 0.8901  $f_A$  in Example II and IXI. The radius of curvature  $R_A$  of the front surface of the first of such simple components is 2.5507  $f_A$  in all three examples, whilst the radius of curvature  $R_6$  of the front surface of the other simple component is 0.8904  $f_A$  in all three examples.

The rear curface  $R_7$  of the rear component of the first member is convex to the front and has radius of curvature equal to 3.3520  $f_A$  in all three exceptes.

The extal thickness  $(D_1+D_2)$  of the meniesus doublet component of the first member is 0.7660  $P_0$  or 0.1719  $\underline{f}_A$  in Example I and 1.0942  $P_0$  or 0.1719  $\underline{f}_A$  in Example II and III. The sum of the axial thicknesses  $(D_3+D_4)$  of the two simple components of the first member is 0.5532  $P_0$  or 0.1242  $\underline{f}_A$  in Example I and 0.7502  $P_0$  or 0.1242  $\underline{f}_A$  in Example I and 0.7502  $P_0$  or 0.1242  $\underline{f}_A$  in Examples II and III.

The arithmetic mean between the 1856 V numbers of the materials of the three convergent elements of the first member in all three examples is 50.72 and thus exceeds the 1856 V number of the divergent front element of the first member by 24.62.

In Example I the maximum value of the ratio of the equivalent focal length of the objective to the <u>f</u>/number of the objective is 2.5  $F_0$ , so that  $\underline{f}_A$  is 1.7620 times such maximum value, whilst in Examples II and III such maximum ratio is 3.571  $F_0$ , so that  $\underline{f}_A$  is again 1.7620 times such maximum ratio.

The position of minimum separation between the sevable second end third numbers occurs when the semivalent focal length of the objective in 7.05  $V_0$  in all three examples. The equivalent focal lengths  $f_3$  and  $f_0$  respectively of the second and third members are respectively 5.8812 and 7.2764 times the minimum value of the ratio of the equivalent focal length of the objective to the f/number of the objective in all three examples.

The moveble second member in all three examples consists of a divergent simple remiscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent element between two divergent elements, and its total axial movement in the range of variation is numerically equal to 1.9942 fg.

The front and rear surfaces  $R_{\rm B}$  and  $R_{\rm B}$  of the simple meniscus component of the occord member respectively have radial of curvature numerically equal to 1.8876  $f_{\rm B}$  and 0.8266  $f_{\rm B}$ . The front and rear surfaces  $R_{\rm LO}$  and  $R_{\rm LS}$  of the triplet component of such member respectively have radial of curvature numerically equal to 1.8634  $f_{\rm LS}$  and 3.9312  $f_{\rm A}$ .

The movable third member in all three examples consists of a doublet component whose front surface  $k_{14}$ , is concave to the front with radius of curvature numerically equal to 0.7164  $f_{07}$ , and the total axial movement of such member is numerically equal to 0.3050  $f_{07}$ .

The internal contact H<sub>15</sub> or the doublet component of the third member is collective and convex to the front and has radius of curvature numerically equal to 0.7164 £<sub>0</sub>. The difference between the mean refractive indices of the untertals of the two elements of such doublet component is .0874 and the difference betweentheir Abbé V numbers 10 30.09.

In all three examples, the various observations are well stabilised in the front three members throughout the reach of variation of equivalent focal length of the objective and also throughout the focuseing range, and the stationers rear monther serves to balance out such residual stabilideed a carations, and also to locate the resultant isage plane in a conventent position. The construction of each number may thus vary widely. In Examples I and II, such rear nember may be . described as of modified Cooks triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a single divergent component and either a convergent doublet component on in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface to used in order to aspist in balancing out the residual stabilized abstrations of the front three numbers without under increase in the overall length of the objective, such asphoric surface being the front purface Rgg of the simple divorgers component, where it can be employed for the minultaneous correction of spherical aberration and come with minimum effect on oblique aberrations. In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six migple components are used, the first three egals being convergent in . order to give the necessary strong convergent power at the front, whilst the next too ore divergent and the slath is convergent. Although no asymptotic surface is used in the

actual example given, come further injuvement in aborration correction could be achieved by incorporating such a surface.

It will be appreciated that, although it is preferred to employ a front member arranged in accordance with the invention of the concurrent British patent application above mentioned, this is by no member essential to the invention and other arrangements of the front member may also be advantageously used in cooperation with the movable system above described.

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a. F. Pallings

ACRES FOR THE APPLICANTS.

22.



## U.S. D. PARTMENT OF COMMERCE Patent Office Address Only: COMMISSIONER OF PATENTS Washington, D.C. 20231

#9

·March 22, 1973

Holoombe, Wetherill & Brisebois 2001 Jefferson Davis Hwy. Suite 307 Arlington, Va. 22202

In re Gordon H. Cook, et al Serial No. 152,254 Filed June 11, 1971 For: Optical Objectives of Variable Equivalent Focal Length

## Gentlemen:

Receipt is acknowledged of papers filed on March 9, 1973

purporting to comply with the requirements of Title 35. U.S. Code, Sec. 119 (1952), and they have been placed of record in the file.

Issue Control Officer Issue and Gazette Division ## 28 1973 A





IN THE UNITED STATES PATENT OFFICE

June 28, 1973

GORDON HENRY COOK et al

Serial No. 152.254

Filed: June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT

U.S. Patent No. 3,736,048

POCAL LENGTH

Exmr. Corbin

Group Art Unit 259

Granted: May 29, 1973

REQUEST FOR CERTIFICATE OF GORRECTION UNDER RULE 322

Honorable Commissioner of Patents Washington, D.C. 20231

Sir:

It is respectfully requested that the Official Letters Patent, above-identified, be corrected as per attached sheet.

Please correct the spelling of the assignee's name to read THE RANK ORGANISATION LIMITED.

The necessary claim of priority and certified copy were filed in the Patent Office on March 9, 1973, however this information was omitted from the heading of the Letters Patent.

Please note that these were clerical errors in the printing of the patent.

Respectfully submitted,

APPROVED

GORDON HENRY COOK et al

OCT 1 2 1973

Joseph F. Brisebois Reg.No. 15, HOLCOMBE, WETHERILL & BRISEBOIS

521-1550

95

## IN THE UNITED STATES PATENT OFFICE

JUL 25 1973

In re application of

GORDON HENRY COOK et al

Fatent No. 3,736,048

Granted: May 29, 1973

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Request for Certificate of Correction filed June 28, 1973

## NOTICE OF CHANGE OF ATTORNEY'S FIRM NAME AND ADDRESS

Hon. Commissioner of Patents Washington, D. C. 20231

Sir:

This will advise that as of August 1, 1973, the

firm name and address of the undersigned attorneys of record in the above case will be:

BRISEBOIS & KRUGER Suite 612 2361 Jefferson Davis Highway Arlington, Virginia 22202

Respectfully submitted,

HOLCOMBE, WETHERILL & BRISEBOIS

Joseph F. Brisebois - Reg. 15,965

## IN THE UNITED STATES PATENT OFFICE

In re application of

November 6, 1972

GORDON HENRY COOK et al

Gr.Art Unit 259

Serial No. 152,254
Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Exr. J. K. Corbin

## LETTER TO OFFICIAL DRAFTSMAN

Hon. Commissioner of Patents Washington, D.C. 20231

Sir:

Please correct the surface  $R_7$  in each of Figures 1-6 to show it as slightly convex to the front, as indicated in red on the attached prints, and charge the cost of this work to our Miscellaneous Account No. 08-2720, Order No. 53.

Respectfully submitted,

GORDON HEARY COOK et al

521-1550 JFB:gw By Jaron F. Brisebols Reg. 15,965
MOLCOMBE, WETHERILL & BRISEBOLS

			(1) .			
Line	Code	Serial Number	Filing Date	2 Status	Patent Number	Patent Date
104	12	309207	9/16:	<u> </u>		
105	1	1	1 = =			
106			-			······································
107						
108			*			
109						
110						
111		271				
112	ļ					
113						
114						
115						
116						
117						18

CONDITION AND STATUS CODES FOR CONTINUING DATA

CODE	CONDITION
01	Now Patented Now Abandoned
71 81	A continuation of (including Streamline) which is a continuation of
72 82 75	A continuation-in-part of which is a continuation-in-part of and a continuation-in-part
73	A substitute for
74 84	A division of which is a division of
86	; said
90 91	and a continuation of
92	, each
NOTE:	When the codes 86 and 92 are used they must be followed by a code in the series 80 (81, 82, or 84); the conditions beginning with "which is".

Table of Contents

#### 4

# MPI Family Report (Family Bibliographic and Legal Status)

In the MPI Family report, all publication stages are collapsed into a single record, based on identical application data. The bibliographic information displayed in the collapsed record is taken from the latest publication.

Report Created Date: 2009-11-24

Name of Report:

Number of Families: 1

Comments:

## **Table of Contents**



## Family1

I records in the family.

US3736048A 19730529

[ no drawing available]

# (ENG) OPTICAL OBJECTIVES OF VARIABLE

EQUIVALENT FOCAL LENGTH

Assignee: RANK ORGANISATION LTD

Inventor(s): COOK G H : MERIGOLD P A

Application No: US 3736048D A

Filing Date: 19710611

Issue/Publication Date: 19730529

Abstract: (ENG) A zoom lens having an improved zooming range and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length fo lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length fC lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5fB and 2.5fB and the total axial movement of the third member in the range lies numerically between 0.25fC and 0.5fC, the minimum axial separation between the second and third members occurring when the equivalent focal length of the object is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between 0.5fC and 1.0fC.

Priority Data: US 15225471 19710611 A I:

Related Application(s): 04/309208 19630916 US ABANDONED

IPC (International Class): G02B01517
 ECLA (European Class): G02B01517
 US Class: 359683; 359688; 359708

Publication Language: ENG Filing Language: ENG

Agent(s): Holcombe, Wetherill & Brischois

Examiner Primary: Corbin, John K.

Assignments Reported to USPTO:

Red/Frame: 04864/0110 Date Signed: 19871021 Date Recorded: 19880502

Assignee: RANK TAYLOR HOBSON LIMITED, 2 NEW STAR ROAD, LEICESTER, LE4 7JO, UNITED

KINGDOM A CORP. OF UNITED KINGDOM

Assigner: RANK ORGANISATION PLC, THE.

Corres, Addr: LERNER, DAVID. LITTENBERG KRUMHOLZ & MENTLIK 600 SOUTH AVENUE WEST WESTFIELD, NEW JERSEY 07090

Brief: ASSIGNMENT OF ASSIGNORS INTEREST.

Legal Status:

 Date
 +/ Code
 Description

 19880502
 ()
 AS
 New owner name: RANK TAYLOR HOBSON LIMITED, 2 NEW STAR ROAD, LEICE: : ASSIGNMENT OF ASSIGNORS

INTEREST.; ASSIGNOR: RANK ORGANISATION PLC, THE\_REEL/FRAME,004864/0110; Effective date: 19871021;